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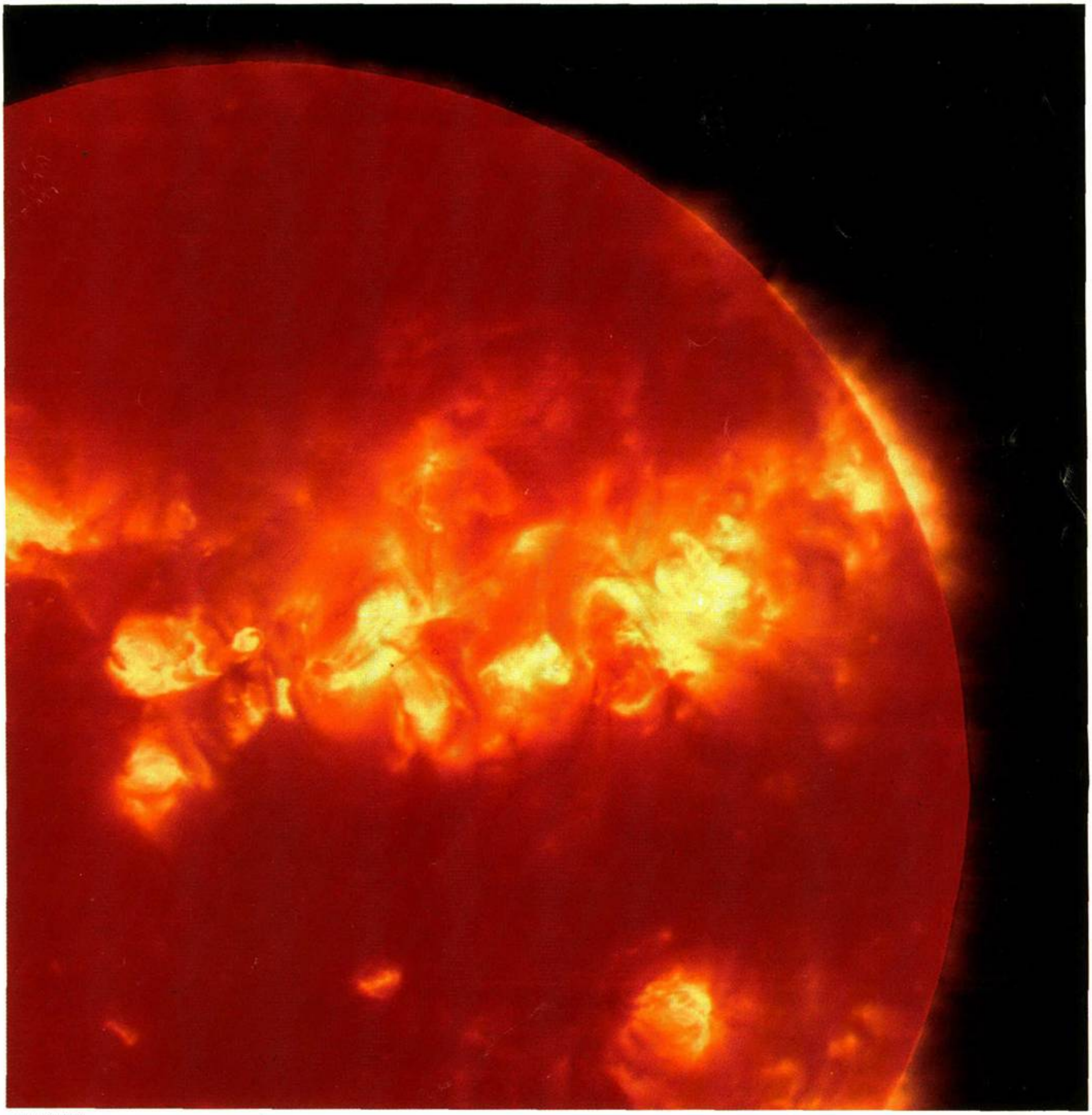

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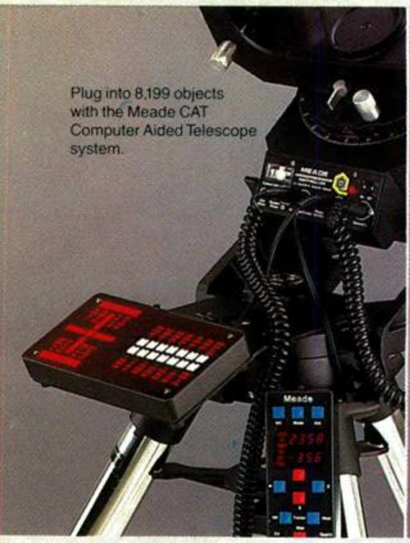

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MEADE PREMIER SERIES 8″ AND

Model	Aperture	f/Ratio	Drive	Wedge	Tripod	Finder	Diagonal	Eyepieces	Accessories[1]
2080/Model 30	8″	f/10	LX6	Standard	Field	6 x 30mm	1.25″	MA 25mm	Package A
2120/Model 30	10″	f/10	LX6	Standard	Field	8 x 50mm	1.25″	MA 25mm	Package A
2120/Model 30H	10″	f/10	LX6	Superwedge	Field	8 x 50mm	1.25″	MA 25mm	Package A
2080/Model 36	8″	f/6.3	LX6	Standard	Field	6 x 30mm	1.25″	MA 25mm	Package A
2120/Model 36	10″	f/6.3	LX6	Standard	Field	8 x 50mm	1.25″	MA 25mm	Package A
2120/Model 36H	10″	f/6.3	LX6	Superwedge	Field	8 x 50mm	1.25″	MA 25mm	Package A
2080/Model 50	8″	f/10	LX6	Standard	Field	9 x 60mm Polar	2″	SP 26mm	Package A
2120/Model 50	10″	f/10	LX6	Standard	Field	9 x 60mm Polar	2″	SP 26mm	Package A
2120/Model 50H	10″	f/10	LX6	Superwedge	Field	9 x 60mm Polar	2″	SP 26mm	Package A
2080/Model 56	8″	f/6.3	LX6	Standard	Field	9 x 60mm Polar	2″	SP 26mm	Package A
2120/Model 56	10″	f/6.3	LX6	Standard	Field	9 x 60mm Polar	2″	SP 26mm	Package A
2120/Model 56H	10″	f/6.3	LX6	Superwedge	Field	9 x 60mm Polar	2″	SP 26mm	Package A
2080/Model 70	8″	f/10	LX6	Standard	Field	9 x 60mm Polar	2″	Package B	Packages A & C
2120/Model 70H	10″	f/10	LX6	Superwedge	Field	9 x 60mm Polar	2″	Package B	Packages A & C
2080/Model 76	8″	f/6.3	LX6	Standard	Field	9 x 60mm Polar	2″	Package B	Packages A & C
2120/Model 76H	10″	f/6.3	LX6	Superwedge	Field	9 x 60mm Polar	2″	Package B	Packages A & C

[1] **Package A:** 115v AC and 12v DC power cords; battery pack. **Package B:** SP 26mm; SWA 40mm; UWA 6.7mm; UWA 14mm. **Package C:** #1200 Electric Focuser; Off-Axis

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$1000
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- **Field Tripod, Wedge, Finderscope, and Accessories**—All Premier models are supplied as complete instruments, ready to set up and operate.

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ECC[2]	EDM[3]	CAT[4]	DRS[5]	Remarks
Optional	Optional	Optional	Optional	*The lowest-cost, fully-upgradable Schmidt-Cassegrains available from any manufacturer.* 30-series SCT's combine f/10 optical systems and the industry's finest motor drive system. "H" models include Superwedge for extreme stability during long-exposure astrophotography.
Optional	Optional	Optional	Optional	
Optional	Optional	Optional	Optional	
Optional	Optional	Optional	Optional	*The lowest-cost f/6.3 Schmidt-Cassegrain ever!* Meade f/6.3 models reduce astrophoto exposure times by 60% compared to f/10 models. Eyepiece for eyepiece, images are 2½ times brighter and fields of view 59% wider.
Optional	Optional	Optional	Optional	
Optional	Optional	Optional	Optional	
Standard	Standard	Optional	Optional	50-series models include hand-held Electronic Command Center and Electric Declination Motor for full dual-axis electronic control of the telescope. Use the 2X speed for precise corrections during astrophotography; flip to 8X speed for image centering and field scanning.
Standard	Standard	Optional	Optional	
Standard	Standard	Optional	Optional	
Standard	Standard	Optional	Optional	Identical to 50-series in specifications, including dual-axis Electronic Command Center, but with fast, wide-field f/6.3 optical system. 2″multi-coated diagonal mirror permits use of wide-angle 2″-barrel eyepieces as well as standard 1.25″-barrel eyepieces.
Standard	Standard	Optional	Optional	
Standard	Standard	Optional	Optional	
Standard	Standard	Standard	Standard	Meade 70- and 76-series are the most advanced and fully-equipped instruments of their types currently available. Included is virtually every accessory required for a lifetime of advanced photo and visual observing: the CAT Computer Aided Telescope system with its 8,199-object memory; Off-Axis Guider/ Illuminated Reticle Eyepiece assembly for long-exposure astrophotgraphy; an assortment of 4 superb eyepieces; and #1200A electric focuser.
Standard	Standard	Standard	Standard	
Standard	Standard	Standard	Standard	
Standard	Standard	Standard	Standard	

Guider; MA 12mm Illuminated Reticle Eyepiece. [2]Electronic Command Center. [3]Electric Declination Motor System. [4]Computer Aided Telescope System. [5]Digital Readout System.

Accessory Coupons!

Accessories available under this special offer include all of the premium Meade photo-visual options that are in greatest demand:

CAT Computer Aided Telescope System—The computerized celestial navigation system that enables the finding of 8,199 objects in seconds. ***Save $200.***

Digital Readout System—Read out celestial coordinates quickly and precisely. ***Save $100.***

Series 4000 Eyepieces—The World's finest oculars for your telescope. ***Save $15 to $25*** on Super Plössls; ***$25 to $50*** on Super Wide Angles; ***$40*** on Ultra Wide Angles.

Plus: Save $10 to $100 on 10 other valuable Meade accessories, from T-Adapters and Off-Axis Guiders to Nebular Filters and Electric Focusers. *Call or visit your Meade dealer today for further details!*

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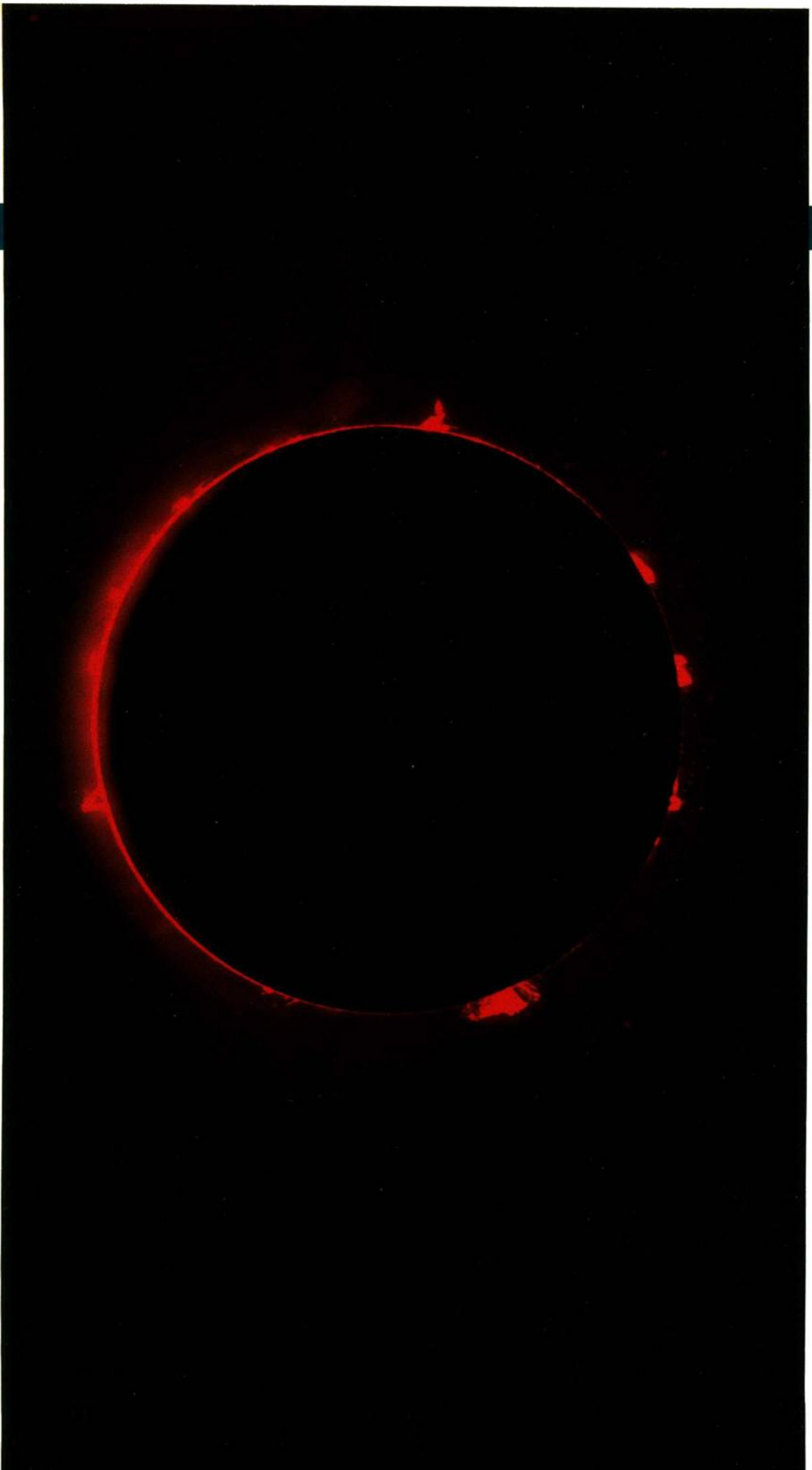
ON THE COVER: Loops and filaments in the Sun's corona are seen in remarkable detail using a new x-ray imaging technique. (See page 32.)



PROMINENT prominences indicate an active Sun. These prominences were photographed by the ASTRONOMY staff on September 29 using a coronagraph.

ASTRONOMY®

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The
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Behind the Scenes

LET'S HEAR IT FOR GROUNDHOG DAY

The Sun has once again begun its journey north, a reassuring sign that winter's end is coming. Each clear morning I see it rise a bit farther to the left of the birch tree that from my bedroom window marks its greatest southern excursion.

I find it deeply satisfying to watch the seasonal cycle of sunrise through the year. Perhaps this is because the Sun's annual return is so rich in associations with the myths of death and rebirth that underlie our culture, or simply because it feels so good to feel warm sunshine on my face. In any case, I've seen the northerly movement of the sunrise point three or four days after the winter solstice for four years running.

In February we celebrate Groundhog Day, one of the least well known astronomical holidays. Precisely in the middle of winter, some six weeks after the winter solstice, we gauge the coming of spring by the groundhog's shadow. Although it smacks of entrails and smoking fires, Groundhog Day is a celebration of the Sun's northward trek.

By June the Sun will be rising through a group of poplar trees far to the north. In summer I seldom see sunrise unless I've set the alarm so that I can rise for some celestial event set in the morning sky — an elongation of Mercury or a promising conjunction of the planets. At the time of the Sun's northern apex, dawn comes early and the nights are short.

Modern life tends to isolate us from natural cycles. We don't have the luxury of rising with the Sun; the clock radio stirs us to action instead. Measured time comes between us and the cycle of Earth and Sun. Ask your neighbor where the Sun rises in midwinter; chances are he will not know.

Ask him the phase of the Moon, or whether Venus is a morning star or evening star. Chances are he will not know and does not care. Does he have an inkling what Groundhog Day means or where the Sun will rise on the first day of spring?

From observations such as this sprang astronomy. On countless winter dawns twenty or thirty thousand years ago, shivering observers watched the same sights you and I see through the windows of our warm bedrooms. "Look," they said to their shivering mates, "the Sun has risen north of where it rose yesterday. Rest assured the Sun will return and warm us again."

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

Does Earth Have a Future?

I must take issue with the Viewpoint by Clark Chapman and David Morrison (November 1989). Although I certainly do not disagree that the possibility exists of a collision between an asteroid or comet and Earth, there are holes in the idea big enough to drive an asteroid through.

The notion that we could "give the object a proper nudge, perhaps by exploding a bomb alongside it," seems at the very least naive. Aside from the problem of transporting bombs to the correct place, I imagine that the only bomb powerful enough to give the object the proper nudge would be a nuclear one. Wouldn't we then run the risk of colliding with thousands of tons of debris and nuclear fallout?

Earth is already facing a far more likely demise from unchecked pollution as well as the rapid depletion of resources such as tropical rain forests, saltwater marshes, and the ozone layer. I strongly suggest that we as individuals and as a society focus our attention on these critical issues that face us with a startling reality. — *Robert G. Crane, Sacramento, California*

If Only I Had a Small Fortune . . .

Can anyone actually afford those telescopes advertised in your magazine? I currently make do with a good pair of binoculars and my husband's theodolite. The latest increase in mortgage rates over here has evaporated a lot of people's extra money, including the savings for my elusive telescope.

Your article several months ago about the lack of a good $200 telescope (Viewpoint, July 1989) made a helluva good point. Won't any manufacturers listen? — *Angela Norcross, Broham, Wiltshire, England*

In Defense of the Newtonian

I enjoyed reading Alan Dyer's article on Schmidt-Cassegrains in the October 1989 issue, but I wish to make a few comments about some of his statements. Dyer's comment that the Meade MTS 8-inch telescope is "difficult to set up and polar align, which makes the scope inconvenient for astrophotography," is a little harsh. I have such a telescope and its pier mount is far more solid than the bouncy tripods he discusses on many other telescopes. I have often walked away during a piggyback telephoto exposure for ten or fifteen minutes and the LX3 drive produced no tracking errors on the finished photograph.

In fairness to Mr. Dyer, the scope can

Paracorr™ Eats Coma

At Last, a *Universal* Coma Corrector for Parabolic Mirrors

There's no question large aperture reflectors like John Vogt's excellent 30" f/3.8 produce deep sky views rivaling those I've seen in major observatories. But his scope, like yours, is limited in field sharpness. The main offender is coma, an aberration which makes stars look like blurry comets. Visually and photographically, the faster the scope the worse the effect.

If we compensate for coma before starlight reaches the eyepiece, then the best eyepieces will be used to fullest advantage, and a sharp full frame 35mm photograph is possible. In sum, my design goals were:

1. maximum reduction in coma and field curvature without compromising spherical aberration and color correction

2. major sharpness improvement for all popular focal ratios

3. equally effective visually or for 35mm film

4. as convenient to use as a Barlow lens

I hope you agree that Paracorr, the coma eater, is the missing link necessary to fully enjoy your "DobNewt."

—Al Nagler

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Paracorr drops in like a Barlow lens. With only a slight 1.15x magnifying factor, an f/4.5 telescope becomes an f/5.17. While optimized for Tele Vue eyepieces, other makes can be used. Of course the better the eyepiece, the better the results. The 1¼" Paracorr is parfocal with most Tele Vue eyepieces. The 2" Paracorr requires about ½" in-travel from your current focus location. Can't be simpler for any scope, any eyepiece, and any 35mm SLR camera.

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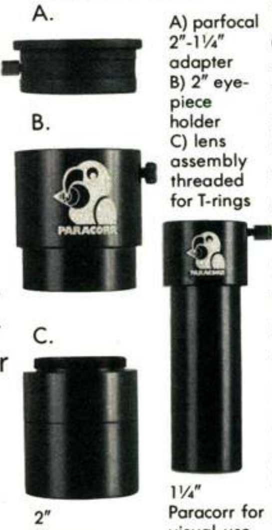

A) parfocal 2"-1¼" adapter
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C) lens assembly threaded for T-rings

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be a chore to set up *if* one uses the Allen screws supplied with the MTS to hold the pier cap in place. On the day I got my scope I went to the hardware store and got some 1/4-20 screws with knurled ends so I could tighten and loosen them with my fingertips. I recommend this step for all MTS owners.

Overall, however, the scope is a joy to use. I haven't regretted buying it for one moment. — *Glenn A. Hopkins, Fresno, California*

Metcalf Mania

The members of the Vermont Astronomical Society are pleased that our favorite son, nineteenth-century comet discoverer Joel H. Metcalf, received widespread attention following the recent apparition of Comet Brorsen-Metcalf. Not only did your magazine cover the comet in detail, but so did newspapers and television stations in the New England area, including the *Burlington Free Press,* Vermont's largest daily.

We are proud of Metcalf's accomplishments. Society members helped organize "Metcalf nights" at which some 250 people viewed the comet. Our society's newsletter carried articles on Metcalf's observing interests, and some of our members even attended church where the Reverend Metcalf once delivered sermons.

I have stood on the little hill near Lake Champlain where Metcalf discovered five of his six comets. In my opinion, Metcalf was the greatest amateur astronomer who ever lived in the United States. As an observer, Metcalf discovered six comets and forty-one asteroids. His keen eye and dedication to observe at all opportunities were rare gifts. As a telescope builder he was known throughout the world for producing fine quality refractor lenses. His accomplishments are an example for all of us. — *Gary T. Nowak, Essex Junction, Vermont*

Correction

Our review of the *Baja Eclipse Pamphlet* (Astronomy Products, November 1989) contained a misspelling of the author's name. The correct spelling is Paul J. Heney.

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P. O. Box 1612, Waukesha, WI 53187. Letters may be edited for length and clarity. □

Viewpoint

HOW TO DEBATE ASTROLOGY

by John Mosley
writer and producer of planetarium shows and supervisor of the educational programs of the Griffith Observatory in Los Angeles, California.

Have you heard that in New York City there's a brief loss in water pressure during the *Tonight Show* commercials, when everyone visits the bathroom at the same time? Our telephones at the Griffith Observatory experience a similar but reverse effect whenever someone claims that a planetary alignment will trigger an earthquake.

In the spring of 1986, a home video program claimed that the 16th-century astrologer and "seer" Nostradamus had predicted an earthquake for Los Angeles. This happened at about the same time we learned that Nancy Reagan had been consulting an astrologer to plan the President's schedule.

If you try to counter a person's emotional beliefs with rational arguments, you'll get nowhere.

When the story broke I found myself as a spokesman for the "opposition," facing a lot of astrologers on radio and TV talk shows. My problem was to explain succinctly why astronomers don't believe in astrology. It was an educational experience.

I quickly discovered that if you try to counter a person's emotional beliefs with rational arguments, you won't reach him or her — especially in ten minutes of air time. First, it takes too long to explain why controlled studies repeatedly demonstrate that astrology is invalid, and much of the audience doesn't have the background to understand the arguments anyway. Second, believers see little reason to take your word for something when what you say contradicts their personal experience.

Astrology seems to work when the astrologer reading the chart is a skillful observer of human nature. The astrologer picks up quickly on what the client would like to hear and tells him whatever will make him happy.

Astrologers also throw around a lot of technical terms like ascendents, trines, aspects, and so on. Many even use a computer. The jargon and paraphernalia help convince the client that the astrologer really knows the subject inside out. The fact that the mumbo-jumbo is used to make the reading sound convincing passes unnoticed by the client, who usually brings to the encounter a willingness to believe.

The whole experience therefore is deeply comforting to people who seek a hopeful future and who need to feel that the cosmos really cares about them personally. Given this, it's hard to see how any statistical argument can counter such a positive personal experience.

The danger, of course, is that if the person seeking advice actually has problems, that person is not well served by a fortune-teller. Astrologers I have talked to justify their practice by claiming to help people, and I'm sure they sincerely believe they do. But through painful experience we've learned it's necessary to restrict medical practice to people who are highly trained, and astrologers are practicing psychology without a license.

What arguments against astrology, then, are effective on a talk show or at a cocktail party? Here are a few of my favorites.

1) We can navigate spacecraft across the solar system with astonishing accuracy. If unknown forces didn't divert *Voyager 2* after a journey of twelve years and 4 billion miles, how can these same forces affect you and me down here on Earth?

2) Planetary influences supposedly lie at the core of astrologers' "science," yet astrologers failed to predict fully a third of the planets in the solar system — which were discovered by astronomers. This is not a minor oversight.

3) Why are horoscopes based on the moment of birth rather than conception? And what does it mean for astrology that in the United States a third of all births happen when the doctor does a Caesarian section or otherwise induces labor? Where's the role of the planets in that?

Astronomers don't dismiss astrology because we can't explain it, but because we *do* understand it and it bores us. A few thousand years ago, when no one understood nature, astrological explanations sounded plausible. We've learned a lot since then, however, and people interested in nature's mysteries should read an astronomy book. That's where the real excitement is. □

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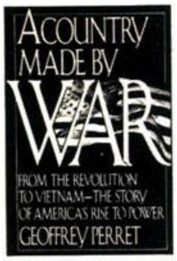
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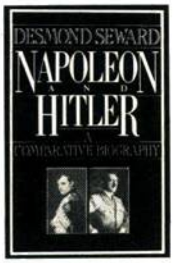
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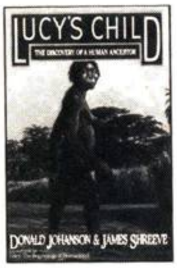
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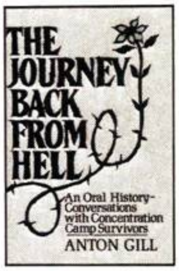
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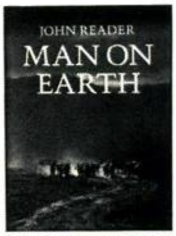
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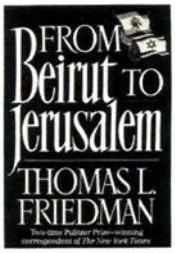
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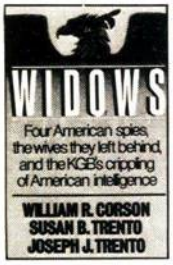
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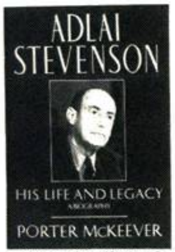
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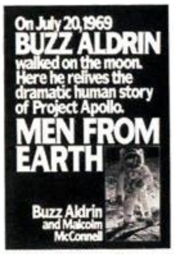
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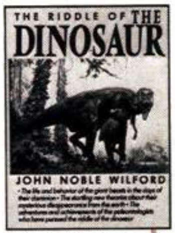
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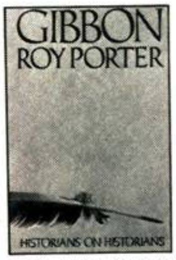
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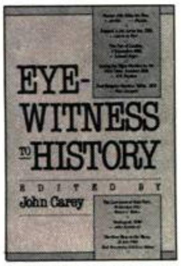
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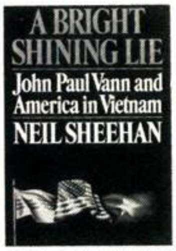
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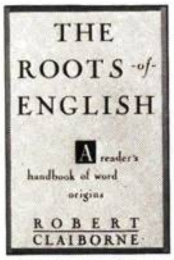
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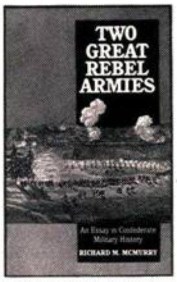
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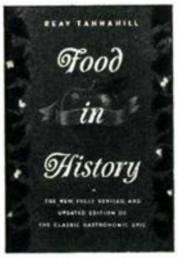
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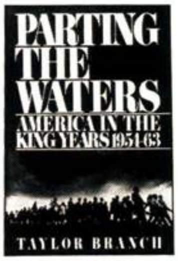
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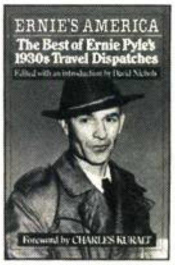
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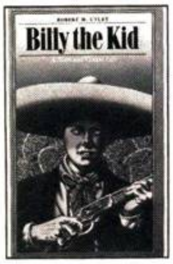
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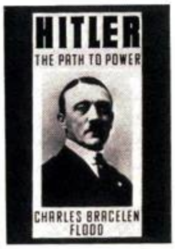
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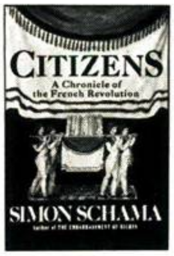
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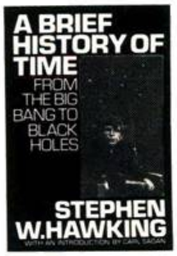
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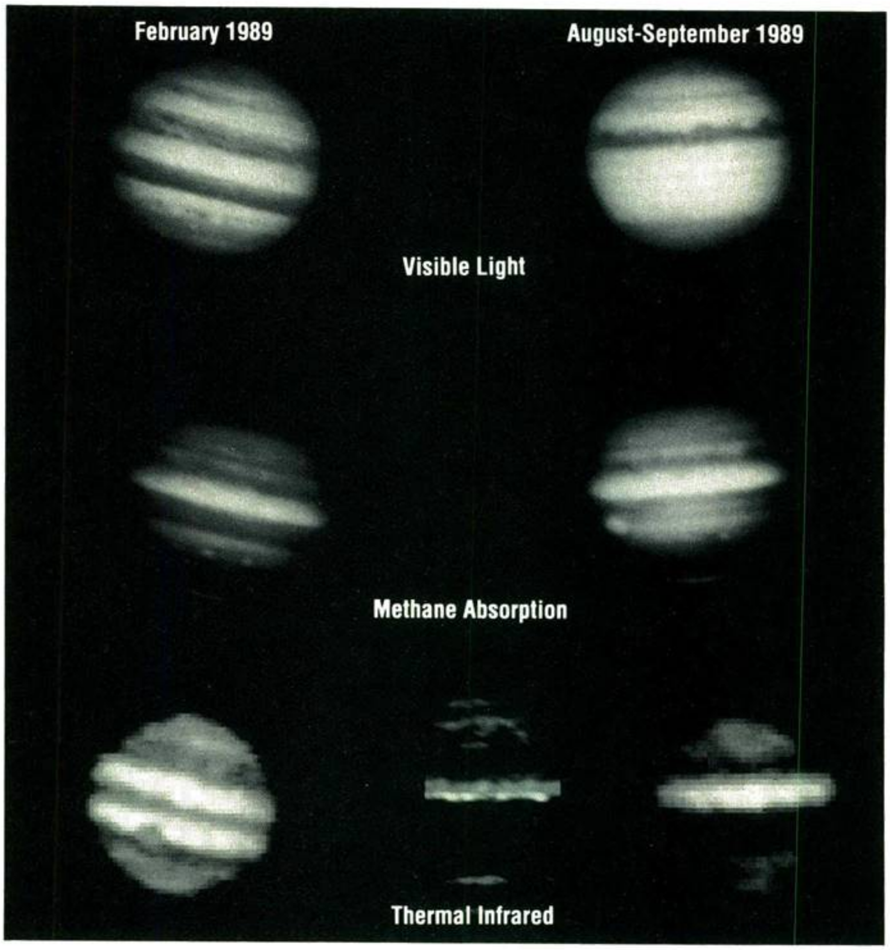
CHANGES IN JUPITER'S SOUTH EQUATORIAL BELT

The South Equatorial Belt on Jupiter is normally a conspicuous dark feature visible together with its North Equatorial counterpart in any small telescope. Last summer, however, the South Equatorial Belt faded from view and remained all but invisible through the end of the year.

The three pairs of photos at right compare Jupiter's appearance at three wavelengths in February 1989 with that of August-September 1989. (North is up in all the photos.) The images in the top two rows were taken by Reta Beebe and David Kuehn at New Mexico State University, those in the bottom row are by a team of astronomers led by Glenn Orton of the Jet Propulsion Laboratory.

The top row shows Jupiter's appearance in visible light. Note how the South Equatorial Belt has vanished in the late summer image. In the middle row the images were taken through filters that isolate absorption by methane, prevalent in the upper Jovian atmosphere. Unlike the visible-light images, these show no trace of the South Equatorial Belt on either of the dates, which indicates that the belt's fading has little to do with high-level clouds or Jupiter's stratosphere.

The images in the bottom row were taken at thermal infrared (heat) wavelengths and, like the visual images, show that the belt has vanished. While the cause for the change remains unknown, Orton speculates that the South Equatorial Belt may have sunk while the cloud layers flanking it on the north and south came together like shutters over the belt and hid it from view.



CHANGES IN THE JOVIAN South Equatorial Belt do not involve methane or the uppermost layers of Jupiter's atmosphere.

NEPTUNE 'TANS' AND FADES AS SOLAR ACTIVITY CHANGES

The planet Neptune "catches rays" and turns darker just like a California beachgoer, say astronomers Kevin Baines of the Jet Propulsion Laboratory and William Smith of Washington University.

Two years ago, astronomers Wesley Lockwood and Don Thompson of Lowell Observatory noted that over a 16-year period Neptune became darker as solar activity climbed toward a peak and brightened as activity declined. They suggested that solar ultraviolet light was somehow acting on Neptune's upper atmosphere to produce the effect, but they did not identify a mechanism.

Based on their computer modeling of the Neptunian atmosphere, Baines and Smith suggest that as solar activity increases, the increasing ultraviolet light induces photochemical changes in the condensed hydrocarbons (such as ethane and acetylene) that are abundant in Neptune's upper atmosphere. Under the flux of ultraviolet light these darken to produce about a 4-percent change in the planet's global brightness.

The key to the process, Baines and Smith note, is that at Neptune the hydrocarbon particles are large, dense, and numerous. Because of this, as they darken the particles sink out of sight relatively rapidly compared to the 11-year solar cycle. Thus at any given time the brightness of the stratospheric haze layer reflects the strength of the solar ultraviolet radiation it has been recently exposed to.

Baines and Smith also calculate that the changes in brightness mean that the temperature of the particles changes by about a factor of two. This, they say, could significantly modify the pattern of high-altitude winds in a manner independent of any seasonal changes. Baines and Smith note that, ironically, while Neptune is currently the planet farthest from the Sun, it also may present the clearest case of a planet's global meteorology being affected by the sunspot cycle.

ULTRAVIOLET LIGHT DESTROYS MARTIAN ORGANIC COMPOUNDS

A team of planetary scientists at NASA's Ames Research Center led by M. Bullock has recently investigated what happens to organic compounds on

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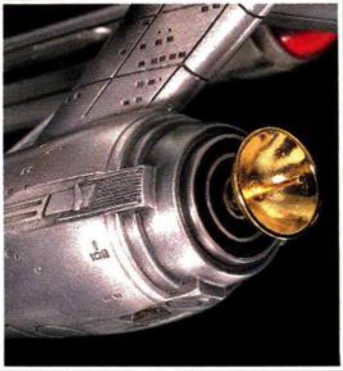

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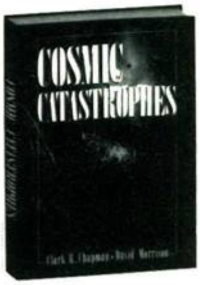
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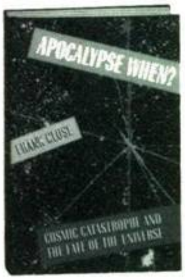
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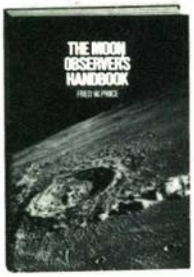
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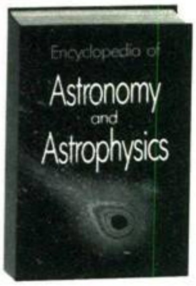
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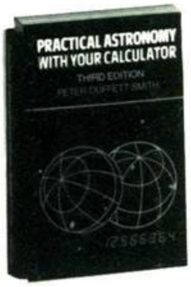
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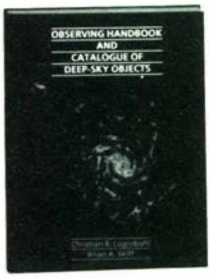
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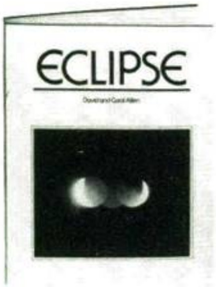
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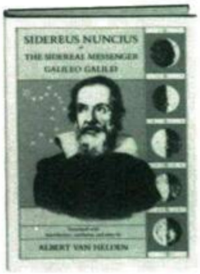
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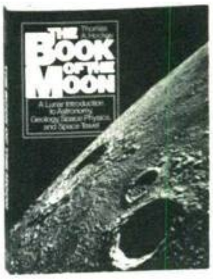
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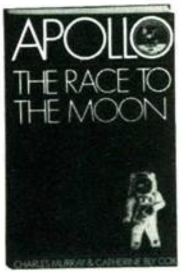
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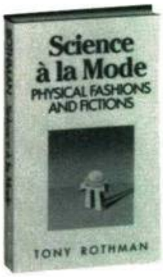
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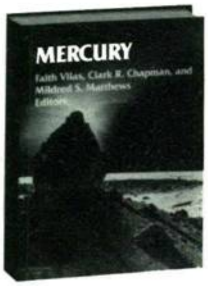
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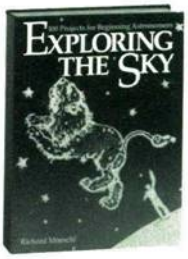
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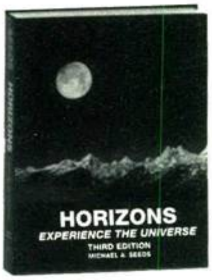
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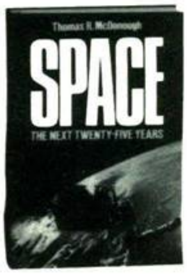
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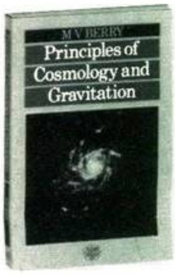
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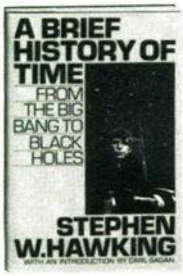
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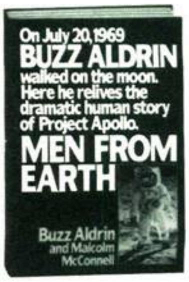
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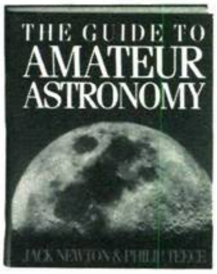
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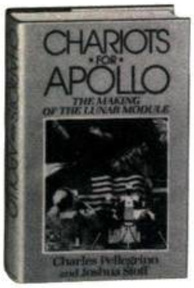
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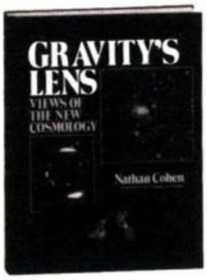
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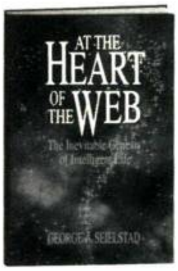
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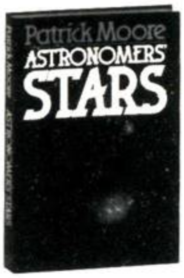
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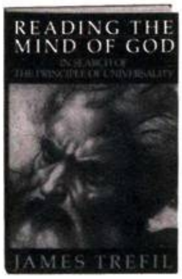
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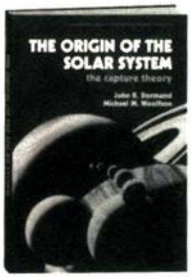
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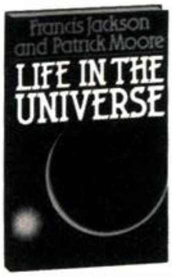
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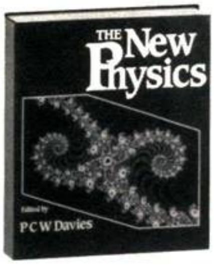
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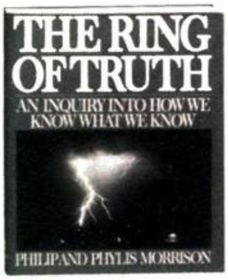
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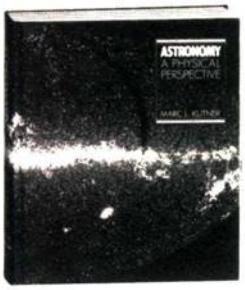
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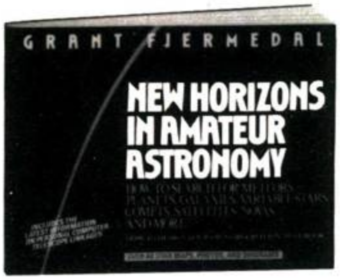
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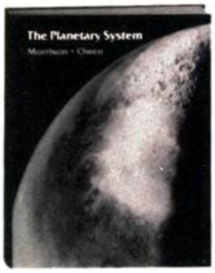
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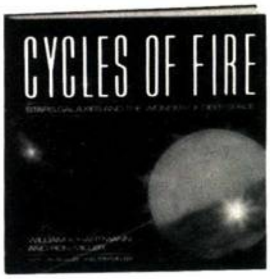
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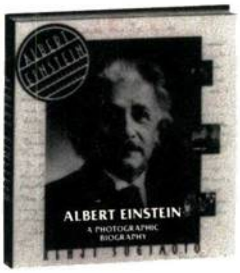
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Astronomy 2/90

the surface of Mars when they are exposed to sunlight. Their conclusion is that ultraviolet light destroys any organic compounds much faster than they are deposited.

The team was spurred to try the experiment by the results of the *Viking* biology experiments, which showed that no organic compounds existed on Mars down to concentrations of a few parts per billion. Since organic compounds are expected to arrive on Mars from infalling meteorites and comets, logic indicated that there should have been some organics present.

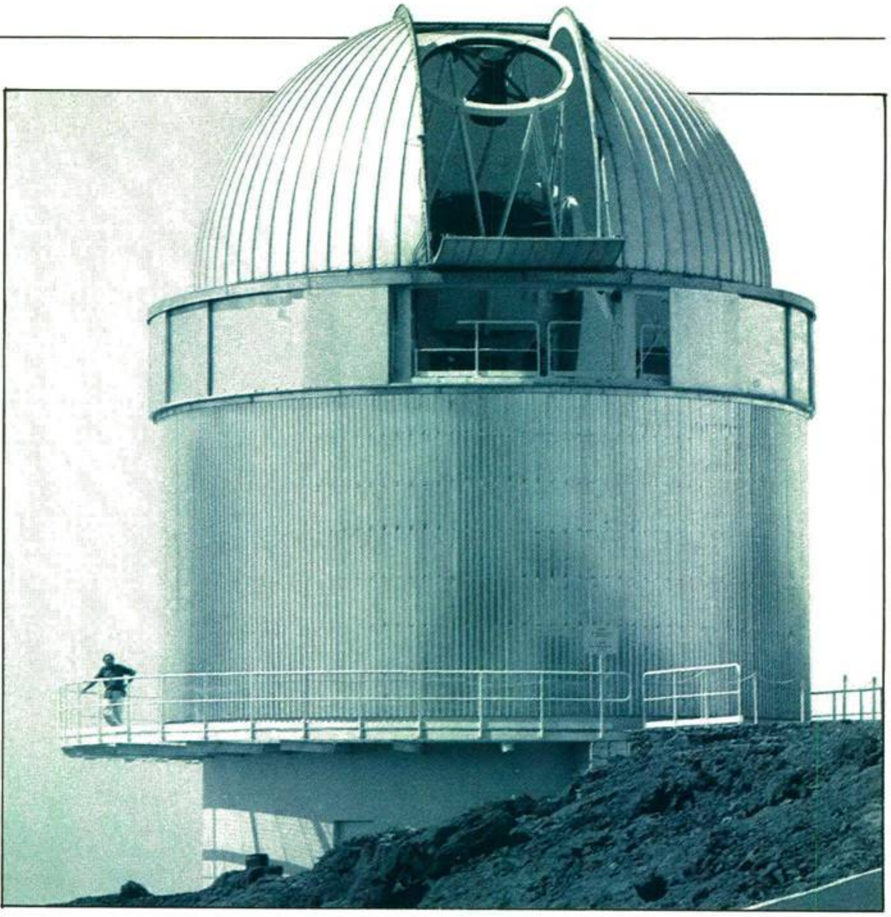
The researchers filled a "Mars jar" with simulated Martian atmosphere and soil, and added the amino acid glycine. They then shone light that had the same spectrum as unfiltered sunlight onto the mixture. The results showed that the abundant ultraviolet radiation in pure sunlight was powerful enough to destroy any organic molecules at a rate that is about 600 times faster than they are deposited on the surface. This explains the *Viking* results and indicates that if Mars ever did have a biology, there clearly must have been something, such as a thicker atmosphere, to ward off the solar ultraviolet.

MERCURY'S POTASSIUM, SODIUM MAY COME FROM IMPACT BASIN

Five years ago astronomers discovered that Mercury has a thin, transient atmosphere of sodium and potassium. A team of astronomers at the University of Arizona's Lunar and Planetary Laboratory now report that the abundance of these two elements varies from place to place on Mercury's surface, with higher than average concentrations being found near the Caloris Basin, a 1,300-kilometer-wide impact scar.

Earlier theories for the origin of the two elements proposed that they came from interactions of the surface rocks with the solar wind or from the vapor released when meteorites struck the surface. Astronomer Ann Sprague of the Lunar and Planetary Laboratory points out, however, that the observed amount of potassium and sodium in the Mercurian atmosphere increases ten-fold when the Caloris Basin lies on the visible hemisphere of Mercury and similarly drops when Caloris passes out of view. This leads Sprague and her coworkers Richard Kozlowski and Donald Hunten to propose the basin itself as the source for the elements.

The astronomers don't think that volcanic activity is the source of the atoms because not enough material is being released. Instead, they propose that the elements are present in the crust of Mercury. Diffusing upward to the surface through the shattered rock of the basin, the elements form a local cloud above it. Once exposed, the individual atoms in the cloud are soon removed by the solar wind, which disperses them over the planet and eventually drives them into space.



READY TO GO TO WORK, the Nordic Optical Telescope will be in use both night and day. Photo by Per Lindstrom, courtesy University of Lund.

NORDIC OPTICAL TELESCOPE INAUGURATED

A major new telescope with unusual design features is now in operation atop the volcanic island of La Palma in the Canary Islands. The 101-inch Nordic Optical Telescope (NOT), built and operated by a collaboration between Denmark, Finland, Norway, and Sweden, boasts the fastest, thinnest, and lightest mirror ever made for so large a telescope. The f/2 primary mirror is only 7 inches thick and weighs less than two tons. The use of a hi-tech mirror makes the entire telescope tube just 15 feet long and allows a correspondingly small and inexpensive dome. The NOT is mounted on a computer-controlled alt-azimuth fork mount.

The NOT mirror is made of a zero-expansion glass-ceramic called Zerodur. Because it is not affected by temperature changes, the mirror holds its figure exceptionally well. Because it is thin, the mirror cools rapidly and does not cause warm air plumes above itself that would degrade its optical performance. In addition, the entire telescope structure and its dome are cooled to ambient temperature to eliminate turbulence. Lund University astronomer and NOT Director Arne Ardeberg said the telescope often resolves one-half second-of-arc detail in celestial objects.

Forty-five pneumatic bellows support the mirror so that it does not bend under its own weight. The bellows hold the mirror so perfectly that less than a quarter-pound of its weight presses on the three points that define its location. Ardeberg said that on its supports, the mirror surface is accurate to one millionth of an inch.

The use of advanced technology has also made the Nordic Optical Telescope one of the least expensive in the world. The total cost of the project was 45 million Swedish crowns, or about $7 million. Ardeberg has pointed out that they could have built two hundred Nordic Optical Telescopes for the cost of the *Hubble Space Telescope*.

The NOT will be used both night and day. At night it will be used for optical observations and in daylight will be used for infrared observations. In total, the NOT is expected to be in use an av-

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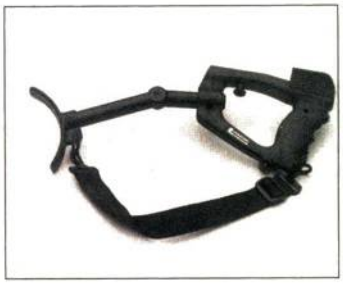

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erage of twenty hours each day. Because of its exceptional optics and site, the NOT will be used for high-resolution observations of distant galaxies and to search for planetary systems around other stars. According to Ardeberg, searching for planets the size of Jupiter orbiting other stars would be a scientifically attractive program, and such searches will have high priority in the near future for the NOT.

INTERGALACTIC RADIO GLOW DISCOVERED

Astronomers have discovered a vast region of radio emission extending across the "empty" gulf between two galaxy clusters. The discovery confirms that the universe contains gigantic radio-emitting zones on a scale larger than clusters of galaxies. The existence of intergalactic radio emission of such proportions may revolutionize astronomers' understanding of how galaxies and voids formed.

Phillip Kronberg and Kwang Tae Kim of the University of Toronto detected the faint emission after reprocessing and reanalyzing radio data gathered four years ago by Gabriele Giovannini and Tiziana Venturi of the University of Bologna, who used the Westerbork Synthesis Radio Telescope in northern Holland. Kronberg and Kim report in the October 26, 1989, issue of *Nature* that the radio emission extends between the Coma Cluster of galaxies and the Abell 1367 cluster, which lies 40 megaparsecs away from the Coma Cluster. The radio emission apparently is not associated with any galaxy in either of these systems.

The type of radio emission the astronomers detected is called synchrotron radiation, a type of nonthermal radiation emitted by electrons that are accelerated around strong magnetic field lines. Kronberg and Kim report that the estimated strength of the intergalactic magnetic field is about 0.3 to 0.6 gauss (gauss is a unit of magnetic field strength), which is remarkably strong considering that typical galactic magnetic field strengths are about 1 millionth of a gauss.

Kronberg proposes that the magnetic field is the fossil of a widespread primeval magnetic field that existed before galaxies formed. If so, Kronberg thinks that astronomers will have to determine the role magnetic fields played in the formation of galaxies, as well as larger structures, such as superclusters and voids.

Space News

COBE MISSION LAUNCHED

NASA successfully launched the *Cosmic Background Explorer* (*COBE*) satellite from Vandenberg Air Force Base in California on the morning of November 18. The satellite's three scientific experiments are designed to study the origin of the universe and to search for the radiation emitted by the first galaxies.

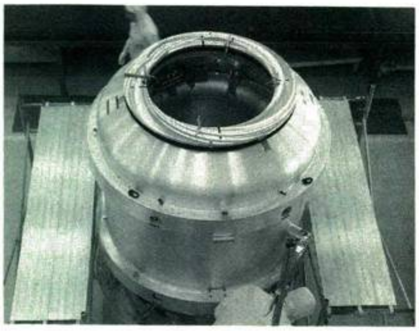
Two of *COBE*'s instruments will examine the cosmic background radiation, a relic of the Big Bang explosion that most astronomers think created our universe. Initially the universe was exceedingly hot, but it cooled rapidly as it expanded. Roughly 100,000 years after the Big Bang the universe had cooled enough so that electrons could combine with atomic nuclei to form atoms. This made the universe transparent to radiation for the first time. It is the remnant of this outpouring of radiation that we see as the background radiation.

The Differential Microwave Radiometer will map the entire sky to search for variations in the brightness of the background radiation. Previous experiments have shown that this radiation is remarkably uniform in all directions, though very slightly brighter in the direction that Earth is moving through space. This uniformity raises a perplexing question for cosmologists: How could our lumpy universe, with matter concentrated in galaxies and clusters of galaxies and seemingly absent from large voids, arise from such non-lumpy conditions? Astronomers hope the radiometer data will supply some clues.

The Far-Infrared Absolute Spectrometer will measure the brightness of the background radiation at one hundred different infrared wavelengths in each of one thousand different directions. This will help determine whether the radiation fits the predicted spectrum (that of a blackbody having a temperature of 2.7 kelvins) or whether there is excess energy at certain wavelengths. Any excess would mean that the universe contains more energy than expected, perhaps in the form of the mysterious and still theoretical cosmic strings. An experiment flown aboard a sounding rocket two years ago indicated that there are substantial variations from the 2.7 K blackbody spectrum, but the results have not been confirmed. With a sensitivity 100 times that of any previous instrument, the spectrometer should be able to tell for sure.

The only way the spectrometer can detect this exceedingly faint infrared radiation is by isolating the detector from all other sources of infrared (heat) radiation. *COBE* accomplishes this by carrying a large Dewar flask, essentially a giant thermos bottle, filled with liquid helium. This keeps the experiment cooled to a temperature of –457° Fahrenheit (2 kelvins above absolute zero).

The third *COBE* instrument, the Diffuse Infrared Background Experiment, is also cooled by liquid helium. The purpose of this experiment is to search for the infrared light emitted by the first galaxies. Astronomers suspect that these primordial galaxies, which formed around 500,000 years after the Big Bang, emit most of their light in the infrared part of the spectrum. The instrument has the capability to detect this light even if it exceeds the surrounding sky brightness by only 1 percent. Because no primordial galaxies have ever been detected before, the background experiment may provide the most exciting observations of the *COBE* mission.



***COBE*'S LARGE DEWAR** holds 211 pounds of liquid helium, which is used to keep the spacecraft's two infrared instruments at a temperature of –457° Fahrenheit.

Because the liquid helium in the Dewar evaporates continually, *COBE* has a limited lifetime. Mission scientists expect the helium to last about a year, at which time the spectrometer and background experiments will end. The radiometer experiment, which does not depend on the liquid helium, is ex-

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THE SPACE TELESCOPE

A Study of NASA, Science, Technology, and Politics

Robert W. Smith with contributions by Paul A. Hanle, Robert H. Kargon, and Joseph N. Tatarewicz

Smith and his colleagues describe the history of the planning, building and funding of the Space Telescope, which has been, to date, the most expensive scientific facility ever constructed. This 25-year-old project — a joint enterprise between NASA and the European Space Agency — promises to yield valuable new insight into the past, present and future of the universe. The astonishingly complex interactions that took place among the scientific community, government, and private industry in the course of its development are also discussed.

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Guy Joseph Consolmagno and Daniel Michael Davis

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pected to operate for at least two years.

COBE was originally scheduled to be launched by the space shuttle from Vandenberg, but after the *Challenger* accident the Air Force decided to indefinitely postpone building a shuttle launch facility there. *COBE* needed a 560-mile-high polar orbit, but shuttles launched from Cape Canaveral can't place a satellite in polar orbit.

NASA eventually decided to launch *COBE* on a Delta rocket from Vandenberg. This required major changes to the spacecraft, however. *COBE*, built for a shuttle launch, was fifteen feet in diameter and weighed 10,000 pounds. To ride into orbit on a Delta it would have to be eight feet in diameter and could weigh only 5,000 pounds.

Project engineers had to totally redesign and rebuild the spacecraft to fit these new constraints, which they were able to do without sacrificing any of the mission's science objectives or the spacecraft's orbital life. The results of those efforts will be seen over the next two years as *COBE* transmits its unprecedented data to eager scientists on Earth.

GALILEO PROBE WORKING PERFECTLY

The seven instruments on board the *Galileo* entry probe have been tested and are functioning perfectly, report mission scientists from NASA's Ames Research Center in Mountain View, California. At the time of the test in late October 1989, the *Galileo* spacecraft was about 2 million miles from Earth, speeding on its way toward Venus, the first checkpoint on the long flight to Jupiter.

Following the test, the instruments were switched off and will not be reactivated again for testing until November. At that time *Galileo* will be a month away from the first encounter (of two) that it will make with Earth to help accelerate it out to Jupiter.

HIPPARCOS BEGINS REVISED MISSION

The European Space Agency's *Hipparcos* satellite has begun scanning the sky in its effort to determine accurate positions and motions for over 100,000 stars. Although a boost motor's failure shortly after launch left the spacecraft in a highly elliptical orbit (see Space News, November 1989), the satellite's other instruments appear to be performing flawlessly.

Amateur News

STAR PARTIES FIND SUCCESS

Amateur astronomers love to attend star parties. Not so long ago going to a star party meant traveling to one of the "Big Three": Stellafane in Vermont, Riverside in California, or the Texas Star Party near Fort Davis. That day has come to a close as a succession of smaller star parties has emerged.

"Our convention emphasizes observing," said Doug Pitcairn, observing chairman of the Halifax Centre of the Royal Astronomical Society of Canada. On August 25-28, 1989, Pitcairn and other members of the RASC held the third Nova East gathering in Fundy National Park, Brunswick, Nova Scotia. "We were clouded out the first night," reported Pitcairn, "so we spent our time studying photographs of Comet Brorsen-Metcalf and listening to the sounds of Fundy: yelping from coyotes, hooting from owls, and clanging from garbage pail lids as raccoons discovered they could pry them off. After talks ranging from solar observing to observing the planets, we retired outside and had a marvelous night of observing. The convention was an unqualified success!"

Another Canadian gathering is the Mount Kobau Star Party, begun in 1984 by the Okanagan Astronomical Society in Okanagan Valley, British Columbia. In 1989 the Mount Kobau group hosted over two hundred astronomers for a party that lasted from August 30 through September 3. This year's speakers included comet discoverer David H. Levy, accomplished deep-sky sketch artist Lucian Kemble, and astrophotographer John Mirtle.

Two star parties back in the States have grown into significant events. Oklahoma's Okie-Tex Star Party, held for several years at the Lake Murray Campground near Ardmore, Oklahoma, regularly sees over one hundred participants. This year the group heard talks by astrophotographer Jack Newton, solar eclipse tour organizer Joel Harris, and film expert Klaus Brasch.

Ohio's Hidden Hollow Star Party attracted 175 participants on September 29 and 30. Held near Mansfield, Ohio, the convention is sponsored by the Richland Astronomical Society and the Warren Rupp Observatory. "This year's lectures were particularly fascinating," reported Robert Bunge, one of the gathering's organizers. "We heard talks by Chicago's Steve Lucas, organizer of the *Sunsearch* supernova hunting network; Brent Archinal of the U. S. Naval Observatory; comet hunter David Levy; and planetary observer Stephen J. O'Meara.

"On Friday night," Bunge continued, "we were able to observe with the 31-inch f/7 telescope at Warren Rupp. Levy located Comet Okazaki-Levy-Rudenko and showed it to a great number of people. Indiana amateur Dan Kaiser used the telescope to discover that a suspected variable star he found (DHK 1) was really a double star. The observing was an unqualified success."

Supporters of one overseas star party have made their resounding success clear. The third annual Whirlpool Star Party, held at Birr Castle in Ireland, drew one hundred attendees on September 22-24. Birr Castle is the historic home of the famous nineteenth-century observer William Parsons, the third Earl of Rosse. Tony O'Hanlon, Secretary of the organizing Limerick Astronomy Club, said "persistent clouds on Friday night delayed the actual start of the convention, which happened in Dooly's Hotel in Birr, on Saturday morning. Later that morning the sixth Earl of Rosse, great-grandson of Parsons, opened the convention and welcomed the first speaker, Patrick A. Wayman of the Dunsink Observatory in Dublin. Professor Wayman's talk eloquently outlined the plans for the *Hipparcos* satellite, which failed during its deployment last summer."

Other talks included a description of astronomy in Czechoslovakia by Jan Cap, president of the Cork Astronomy Club. "Delegates were amazed by the sizes and numbers of telescopes in this country," said O'Hanlon. Dominic Doyle of St. Patrick's College delivered a lecture on infrared astronomy. Andy McRea of the Irish Astronomical Association gave a presentation on the structure of the Milky Way, from the earliest thoughts up to today.

Societal interest in astronomy seems to be on the rise. No longer will three gatherings of amateur astronomers dominate the scene as they have in the past. These new star parties are vying for the growing interest in getting together to look at and talk about the stars. □

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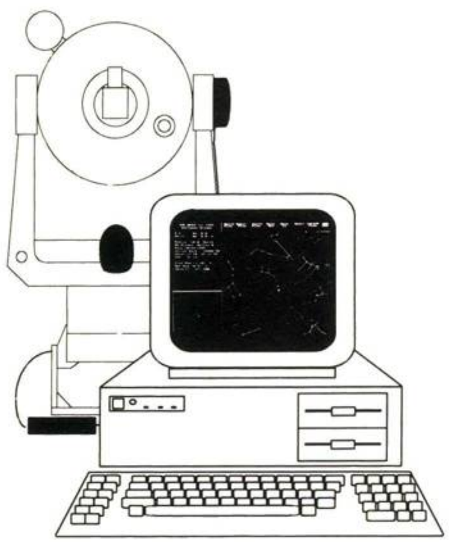

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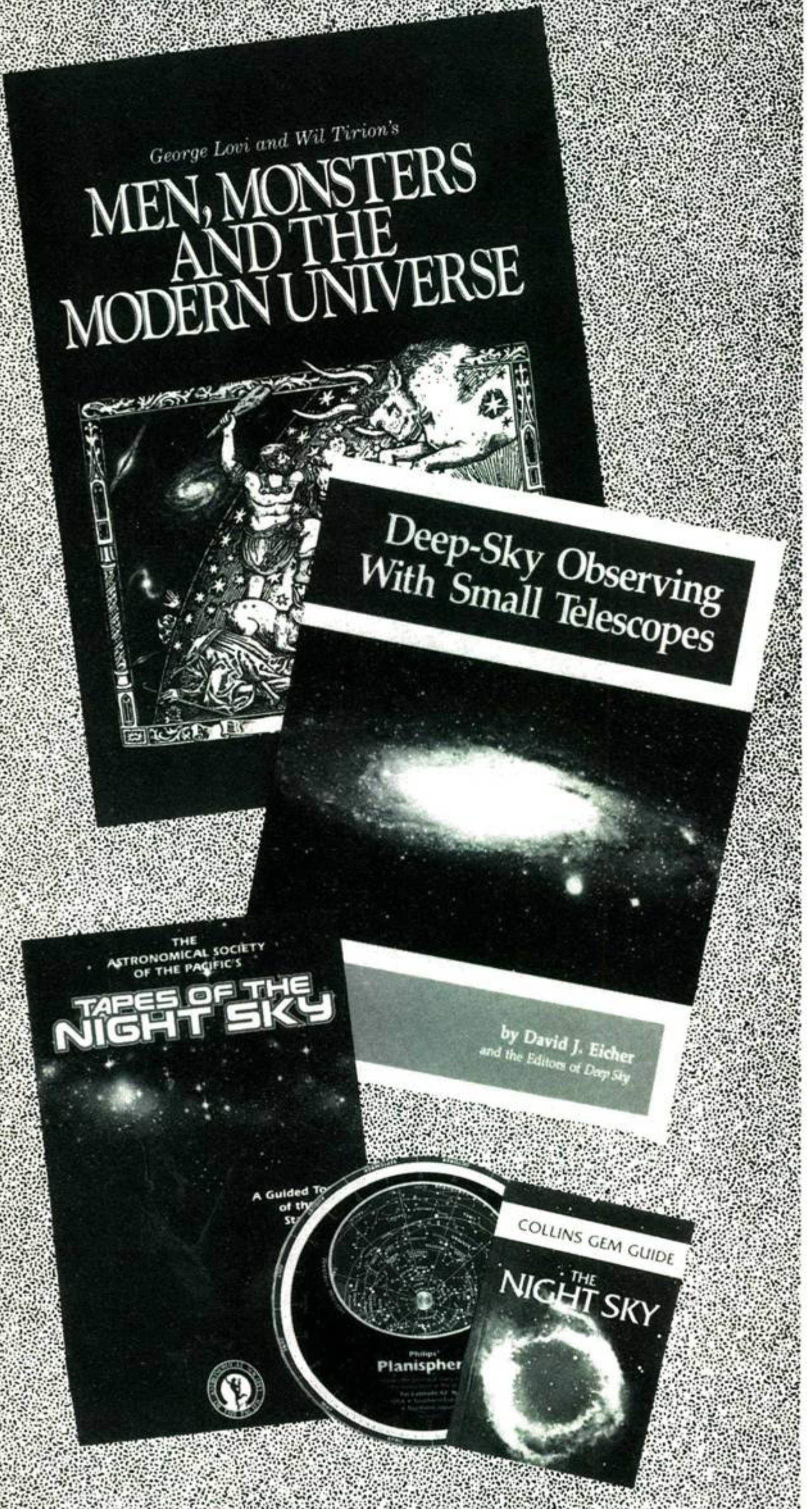
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REALM OF THE HOTTEST STARS

The hot nuclear fires within stars dictate not only their lives but their deaths.

by James B. Kaler

THE HELIX NEBULA is ionized by a central star with a temperature of about 110,000 kelvins. (Anglo-Australian Telescope Board, © 1979.)

As darkness falls on winter evenings, you can still see the great constellation Cetus the Sea Monster backing toward the western horizon. You might recognize the star Menkar, "the nose," which the Hyades conveniently point to, or the brighter Deneb Kaitos, the "whale's tail," a 2nd-magnitude star in a fairly blank region of the sky near the southwestern horizon.

If you watch Cetus over a long period you may see a third star positioned midway along the "neck" of the sea monster. This star is sometimes visible and sometimes not. Most of the time it languishes around 10th or 11th magnitude. But for two months every 330 days or so it may reach Menkar's stature (about 3rd magnitude), or perhaps rival Deneb Kaitos.

This pulsating star is Mira, whose name means "the wonderful." What makes Mira all the more wondrous for astronomers is that it is a star in transition. Mira recently evolved from a normal hot star to a cool giant and is now on its way to becoming one of the smallest classes of stars known, a white dwarf.

Thousands of Mira-type stars are known. A surprising number are visible at maximum brightness (R Leonis and R Cygni, for example) with the naked eye or binoculars. Miras are red giants, old stars that have "retired" from the main occupation of all stars — burning hydrogen. A sequence of normal, hydrogen-burning stars emerges when the effective surface temperatures of all stars are plotted against their luminosities in a graph known as the Hertzsprung-Russell, or H-R, diagram. About 90 percent of all stars lie along a diagonal track running from the bottom right part of the graph (cool red stars) to the top left (hot blue stars). Astronomers call this track the main sequence, and it is an important tool in stellar research.

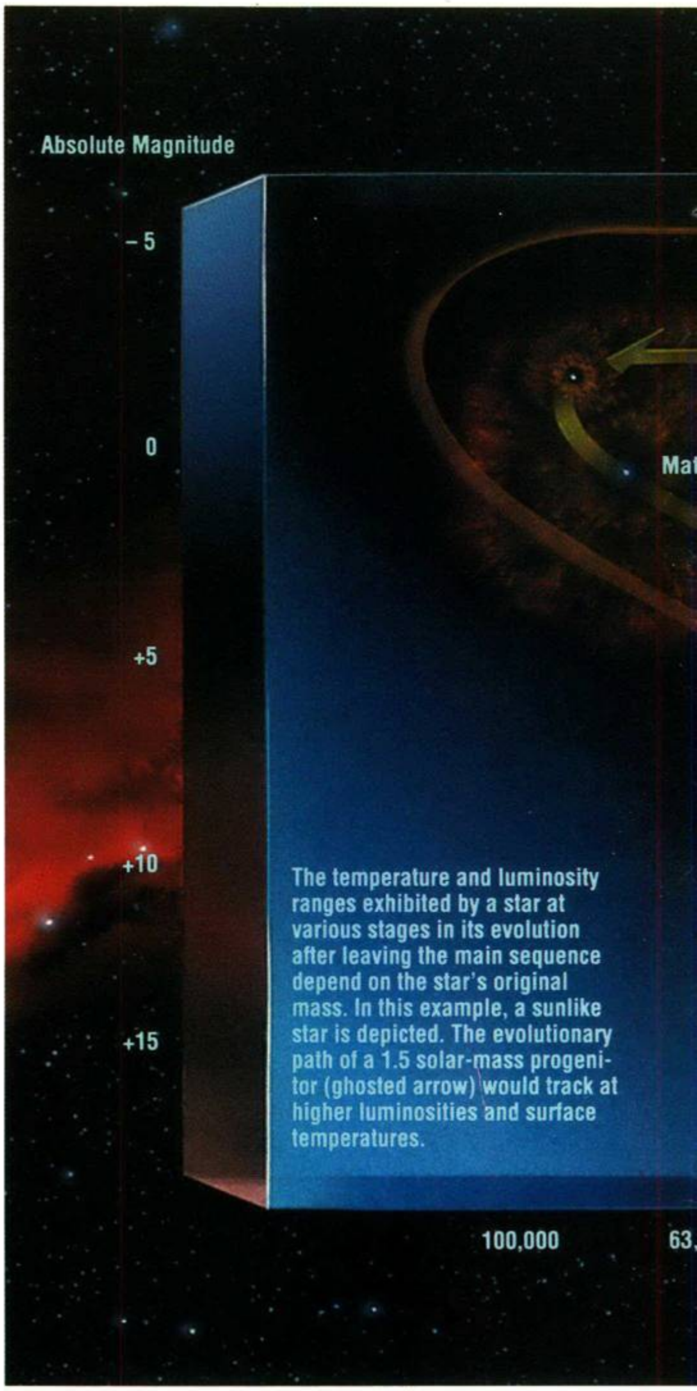
Another kind of standard that astronomers rely upon is the spectral classification system. Based on absorption features in their spectra, which can be related to the temperature (or color), stars are assigned letters that correspond to positions on the main sequence. These letters — O, B, A, F, G, K, and M — range from the hot blue stars to the cool red dwarf stars, respectively. Furthermore, each category contains various subdivisions between 0 and 9 that represent temperature and color differences within that category. The Sun, for example, is classified as a G2 star and sits squarely on the main sequence.

Mira, however, sits well off the main sequence toward the upper right corner of the H-R diagram. Classified as an M7 giant, Mira is intrinsically bright, but cool. It is bright because its huge size affords more surface area from which to emit light, but cool because its radiation permeates a volume large enough to fill the orbit of Mars. Its surface temperature is about 3000 kelvins, in contrast to the 6000 kelvins of our Sun.

Mira stars also represent the beginning stages of the "planetary" nebula, an expanding shell of dust and gas ejected from a giant star as a result of its luminosity and instability. Many planetaries look like glowing disks (hence the name planetary) or smoke rings and are popular deep-sky showpieces. The Dumbbell and the Ring nebulae are two such examples.

The Fire Within

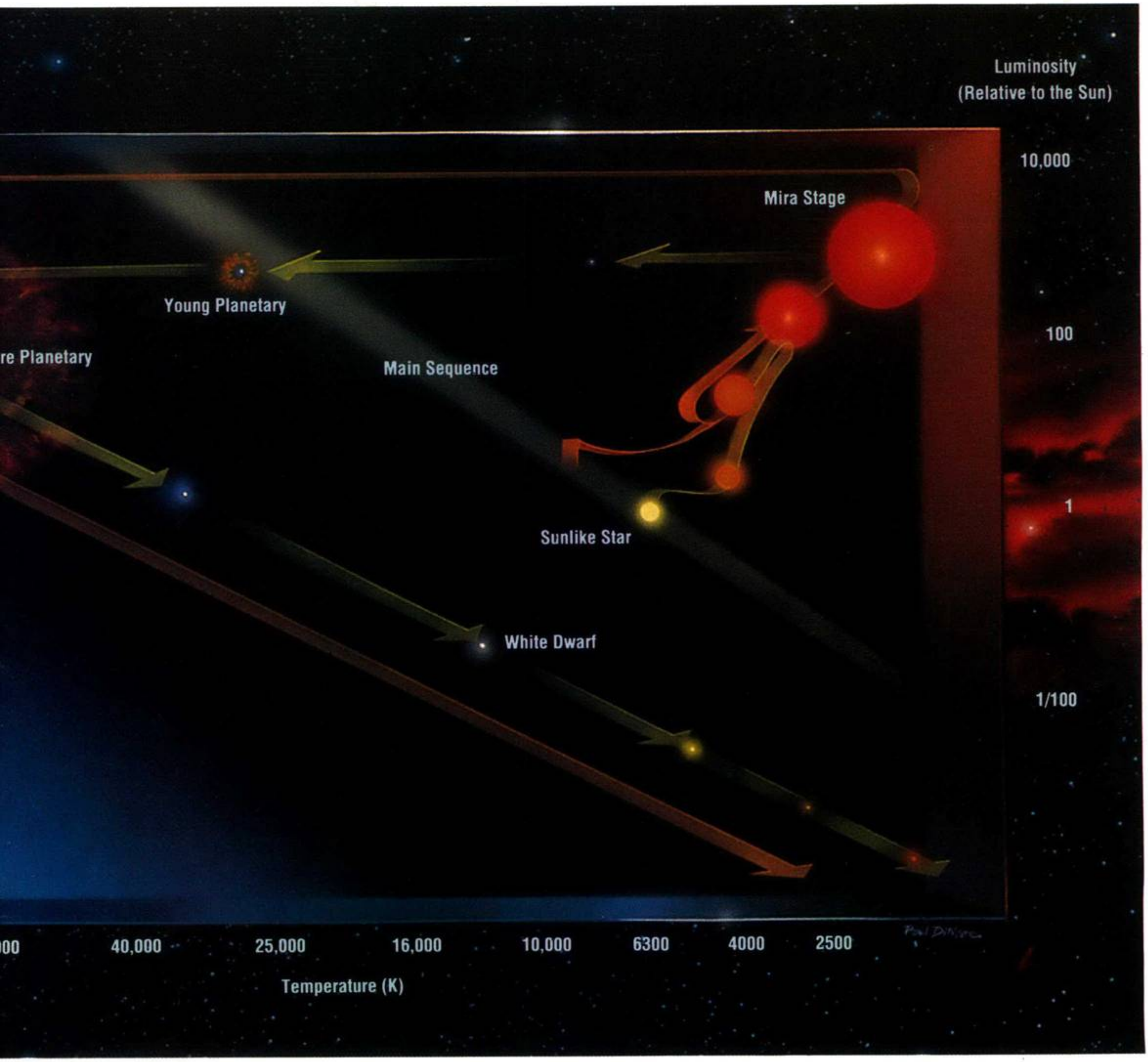
In an evolutionary context, planetary nebulae are the chief transitional links from the giants to the white dwarfs. Miras, however, precede the planetary stage and that's what makes the central stars of planetary nebulae a fascinating and worthwhile study. Astronomers want to know what happens inside a star that ultimately leads to this transition. The best way to find out is to study the star's core — the planetary nucleus — and what happens to it once it runs out of fuel.



The temperature and luminosity ranges exhibited by a star at various stages in its evolution after leaving the main sequence depend on the star's original mass. In this example, a sunlike star is depicted. The evolutionary path of a 1.5 solar-mass progenitor (ghosted arrow) would track at higher luminosities and surface temperatures.

Astronomers know that when a star's long period of hydrogen burning finally ends, interesting things can happen. The high-mass stars (in excess of 5 or 10 solar masses) can explode as supernovae, but these are rare occurrences because the stars that make supernovae are equally rare. Most supernovae, in fact, are observed in distant galaxies, making them even more inaccessible. (Supernova 1987A in the Large Magellanic Cloud was the nearest example in over 380 years.)

To understand the nature of stars we need to study the details of all phases of their evolution. Fortunately,



the lower-mass stars (under 10 solar masses) are near and plentiful enough to accommodate astronomers in this research. Although less spectacular in death than their volatile high-mass cousins, the low-mass stars have the potential, even more than supernovae, to teach us how the hot nuclear fires within stars dictate their lives and deaths.

Nuclear fusion takes place only in the central region of a star where temperatures and pressures are high enough to allow atomic nuclei to fuse with one another. When the core's hydrogen is exhausted, the core can no longer support itself and it contracts. Contraction increases pressure and temperature, the combination of which fires up nuclear burning in a shell where the core and the previously inert envelope meet. The resulting heat energy causes the overlying envelope to balloon to giant proportions. The star becomes so large that the surface layers cool and we see a red giant.

Ultimately, the core becomes so hot that the helium nuclei, the "ashes" of the first burning stage, can themselves fuse into carbon and oxygen. These new reactions stabilize the core of the star, causing it to dim somewhat as the star's outer layers now contract. For a while, though not nearly as long as the main-sequence lifetime, the star quietly burns its helium in a now-tiny, dense core that is surrounded by a hydrogen-burning shell. Stars such as these are found in the horizontal branches of the H-R diagrams of globular clusters. Arcturus and many other K-type giants are examples.

But the helium too must run out, and when it does the nuclear fire dies and the core contracts once more. The resulting higher heat and pressure brought on by further contraction causes the star's outer envelope to expand even more than before, leading to an increase in brightness. Now the star consists of a dead carbon-oxygen core surrounded by a shell of still-burning helium, which is itself encased in a shell of fusing hydrogen. In this state conditions below the outer layers cause the star to pulsate in both size and brightness. The result is a Mira variable.

This layering process of helium- and hydrogen-burning shells does not continue, however. It is halted in these lower-mass stars by the loss of the envelope described earlier, which relieves the great weight of the overlying layers. The core cannot be gravitationally squeezed any further and this prevents the temperature from rising to the point at which the carbon would burn. Even without further nuclear burning, however, the core would cease contracting as the electrons, stripped from their parent atoms under such hot conditions, enter into a strange quantum-mechanical state called "degeneracy." In a normal gas we can increase density by compressing it. But at the very high densities of a star's collapsed core — thousands of kilograms per cubic centimeter — the electrons reach a density limited by quantum mechanics. At that limit, the electrons are packed so tightly together that they exert a counterpressure that prevents them from being squeezed still closer, and the contraction halts.

Even this phenomenon has its limit, however. If the core has a mass greater than 1.4 solar masses, the gravitational squeeze is so powerful that not even electron degeneracy can hold it back. Further collapse is inevitable, resulting in neutron degeneracy and a neutron star. In the simplest terms, stars that produce white dwarfs must start out with a mass small enough that the core — the planetary nucleus and the eventual white dwarf — cannot grow larger than this limit. Astronomers think this critical initial mass is around 6 or 8 solar masses. Above this amount a star may explode; below it, a quieter death is assured. But to fall within the range some of these stars may have to lose up to 75 percent of their mass! They accomplish this by the production of planetary nebula.

The Planetary Shells

Just how the planetary nebula forms is itself a subject of considerable current controversy. The older of two competing ideas suggests that as a Mira star approaches the end of its helium-burning period, after it has already lost a good portion of its mass, it develops a "superwind" that significantly increases the rate of mass loss. The superwind virtually strips the star of its remaining envelope, which in turn produces a thick, obscuring cloud of expanding dust and gas. As the cloud grows and thins, however, it leaks some of the energetic starlight and we see a planetary faintly surrounded by a much larger sphere of matter expelled during a prior ejection.

A newer theory suggests that instead of a high-mass superwind, the star develops a lower-mass but *high-speed* wind that rams into the previously ejected envelope, compressing it into what we later witness as the planetary. Astronomers are actively trying to decide which of the two scenarios is correct, but the verdict is not yet in.

Whatever their origins, planetaries are obviously created in some fashion; well over a thousand have been cataloged. Their masses appear to average about 20 percent that of the Sun but the contractions may be quite large. In their youth they are small, with diameters no greater than a few thousand astronomical units and densities well over 10,000 atoms per cubic centimeter — still a good vacuum by Earth standards. In this state they may appear as no more than stellar dots on a photographic plate. The nebulae expand slowly, typically at about 20 kilometers per second, though again with a large range. After several tens of thousands of years the nebulae grow so huge that they span the distances between stellar neighbors — here to Alpha Centauri, for example — and their densities drop to a few tens of atoms per cubic centimeter, not much denser than interstellar gas. Clearly these lovely objects are ephemeral things, dissipating into space in a mere 50,000 or so years from the time they were formed.

What Planetaries Are Made Of

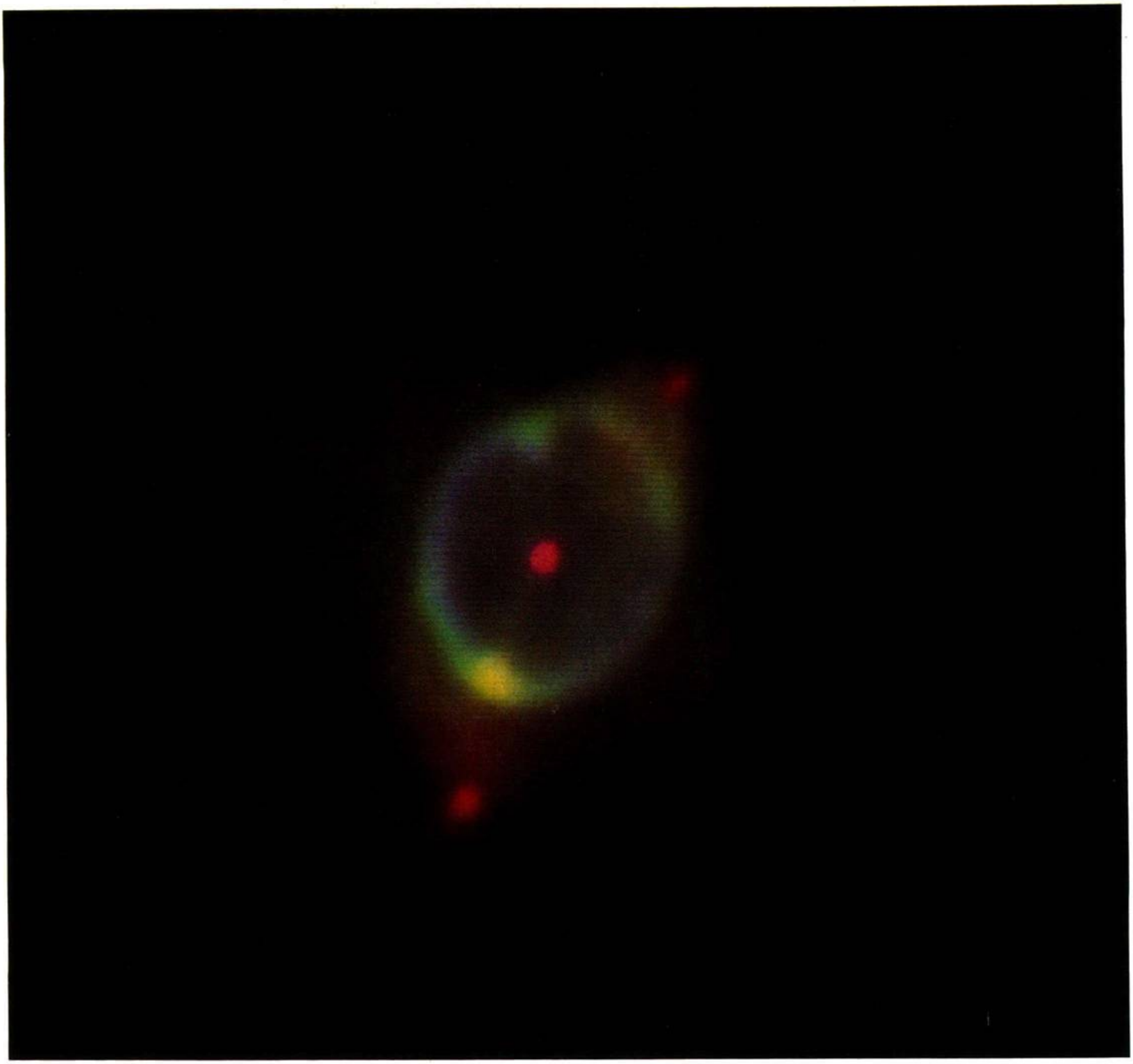
One of the more remarkable aspects of the planetaries are their chemical compositions. Astronomers learn what a planetary is made of, as well as its temperature and density, from the nebula's spectrum. A spectrum enables astronomers to trace the parent star's evolution as well as to place it in context with other planetaries and their central stars.

The spectrum of a radiating body is simply a record of the array of colors produced. Using a prism we can spread out sunlight or starlight much like a rainbow for direct analysis. For scientific measurement, astronomers graph the brightness of the object in each wavelength of the radiation. To measure wavelength, astronomers use a length unit called the angstrom, which is one hundred millionth of a centimeter. A wave 8000 angstroms long will appear deep red to the eye, one of 5000 angstroms green, and 4000 angstroms violet.

If we look closely at a highly resolved spectrum of a star we notice that it appears chopped up with dark lines. These lines are where light has been absorbed, or subtracted out, by the different kinds of atoms in the star's atmosphere. The lines occur at specific wavelengths that allow astronomers to determine what kind of atoms are in the gas. Hydrogen for example, removes radiation at a wavelength of 6563 angstroms (H-alpha) in the red, at 4861 angstroms (H-beta) in the blue, and at several other positions. Based on their line strengths, which are determined by temperature, stars are classified using the O, B, A, F, G, K, M sequence.

If the gas density is low, as it is for interstellar gas or for a circumstellar cloud, we see the reverse type of spectrum: a nebula that *emits* light at these specific wavelengths rather than absorbs it. In the instances of planetaries (as well as for the great diffuse nebulae of the Milky Way such as the Orion Nebula), a hot central star produces so much high-energy ultraviolet radiation that it ionizes the gas, that is, it strips electrons from their parent atoms. When the electrons collide and recombine with the electrically charged nuclei, they emit energy, producing the characteristic bright emission lines of the spectrum: H-alpha and H-beta, and a variety of helium, oxygen, carbon, and nitrogen emissions.

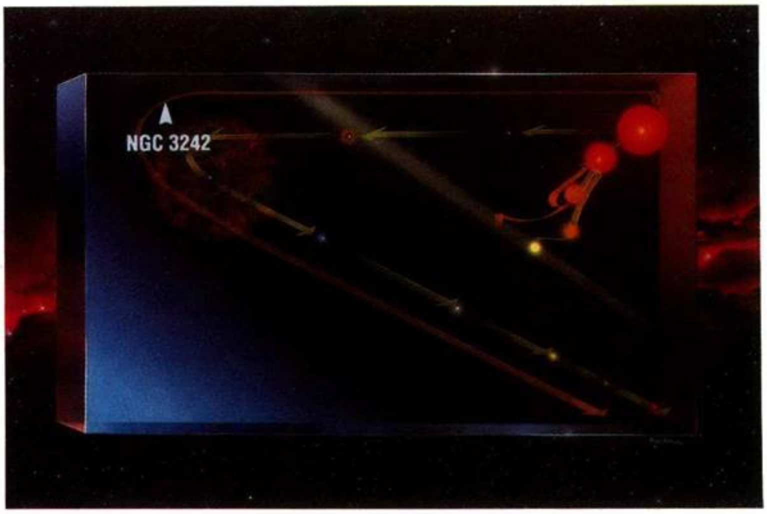
But even stronger than these are a set of powerful features called "forbidden lines." These lines are produced by oxygen, neon, nitrogen, and a variety of other elements when an electron that has been freed from a hydrogen atom slams into an ion (an atom with

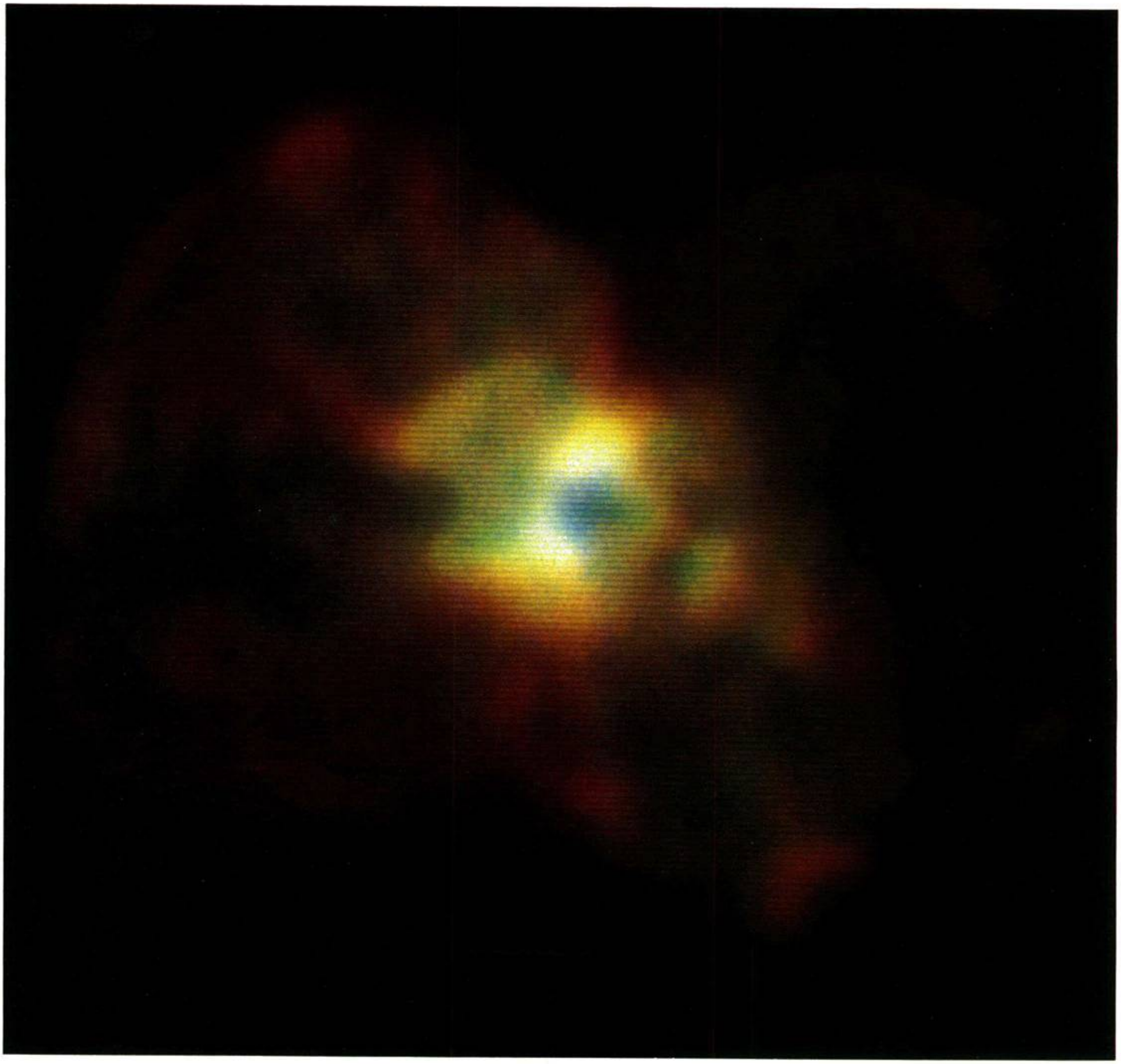


NGC 3242's CENTRAL STAR shines within a well-defined inner gas shell (blue), which is itself surrounded by gas (yellow). NOAO photo courtesy of Bruce Balick.

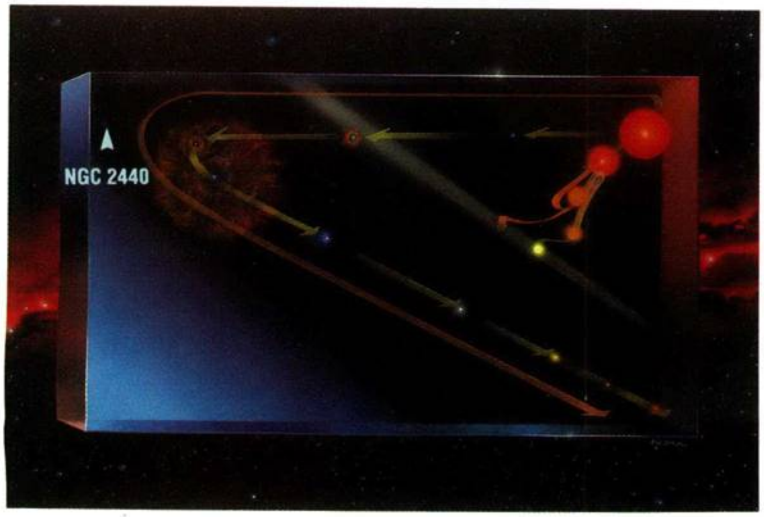
one or more electrons removed) of one of these heavier atoms, giving it energy that it subsequently radiates. The particular electron jumps that produce the emissions are actually not allowed by simple quantum mechanical rules and are hence called "forbidden," although more sophisticated mathematical treatments do allow them. Only under conditions of low density with high mass do the forbidden lines compete with the other lines, and in the planetaries, conditions are ideal.

Based on quantum theories of how these forbidden lines are produced, astronomers interpret the line strengths in terms of compositions. It is common to find





BURIED WITHIN COMPLEX NEBULOSITY, the central star of NGC 2440, at 220,000 kelvins, is one of the hottest stars known. NOAO photo courtesy of Bruce Balick.



nebulae that are notably enriched in helium (up to two times the Sun's helium abundance), nitrogen (sometimes by over a factor of ten), and carbon. These abundances result from eons of nuclear burning. The stars circulate the by-products of their fusion upwards into the envelopes, which are later ejected into space by stellar winds.

Thus, in principle, astronomers can use nebular compositions to literally look inside the giant predecessor stars of the planetaries and to test theories of stellar structure, evolution, and all the processes that contribute to the ultimate abundances of the nebulae. Based on these theories, detailed calculations have been made of the nitrogen and helium abundances expected in planetary precursor stars. The observed and predicted compositions actually show some loose agreements, enough so that at least a rough estimate can be made of the mass of the original star.

Heating Up the Central Stars

As the planetary nebula evolves, so does its nucleus. These stars are extraordinarily bright as they develop out of their cocoons. Depending on their masses, their luminosities range from about 1,000 times that of the Sun's luminosity at half a solar mass (about as small as they get) to close to 100,000 times near the white-dwarf limit.

No matter what its mass, a central star first heats up at a constant brightness. During this period the star shines by the nuclear burning that occurs in a thin hydrogen or helium skin left behind that still blankets the true core. At first the temperature is just 25,000 K or so. At this temperature the star produces only enough ultraviolet radiation to illuminate the inner portion of the surrounding shell, and the star appears bright relative to the planetary. Then, as the envelope is eaten away from below by fusion and from above by winds, its surface temperature increases and it contracts. As a result it brightens in the ultraviolet, but at the expense of the optical radiation. The star's increased energy lights up more and more of its surroundings as the gaseous shell expands and thins. Finally the radiation bursts through the outer edge allowing us to see the full nebular structure, which often includes concentric rings of dust and gas, the previous episodes of mass loss.

As the nebula brightens in response to the star's greater energy input, the star actually becomes fainter to the eye because successively more radiation emerges in the form of high-energy invisible wavelengths. Like a tone that vibrates too rapidly for the human ear to hear, a star that emits much of its radiation at frequencies beyond what the eye can perceive disappears entirely within the brightening nebular glow. We then see a planetary with no apparent central star.

Finally, at a temperature also dependent on the star's original mass, the star stops heating and starts to cool and dim, even in the high-energy ultraviolet. Eventually the nebula expands to the point where its light is spread over so much sky its surface is barely visible. The star now re-emerges and we see a faint central star — at its dimmest only a few times brighter than the Sun — within a large, tenuous nebula.

The stellar evolution theory that predicts how a star's temperature and luminosity change according to time and mass is well supported by observations. The temperatures of the central stars are fairly easy to find, as Hermann Zanstra, one of the great founders of this field of study, discovered in the 1920s. As long as all the starlight is absorbed by the nebula the hydrogen radiation (or in the case of hotter stars, helium radiation as well) from the planetary corresponds to the star's ultraviolet input. Thus a measurement of the brightness of a hydrogen or helium line can tell astronomers how much invisible ionizing radiation is coming from the star. Astronomers can compare this quantity to the visual magnitude and derive a ratio that is exquisitely sensitive to temperature. The star's luminosity follows from this Zanstra temperature, as well as from the magnitude and distance.

A variety of studies have found reasonable agreement between prediction and observation up to a temperature of about 125,000 K. Above this limit stars with higher temperatures are not apparent. The problem is strictly observational: Stars hotter than this simply avoid easy detection. They can be found, however, by using sophisticated electronic imaging techniques under the best-possible observing conditions, so we know they are there. A good example is the nucleus of NGC 2440 in the constellation Puppis — an astounding 220,000 K.

Winds and Compositions

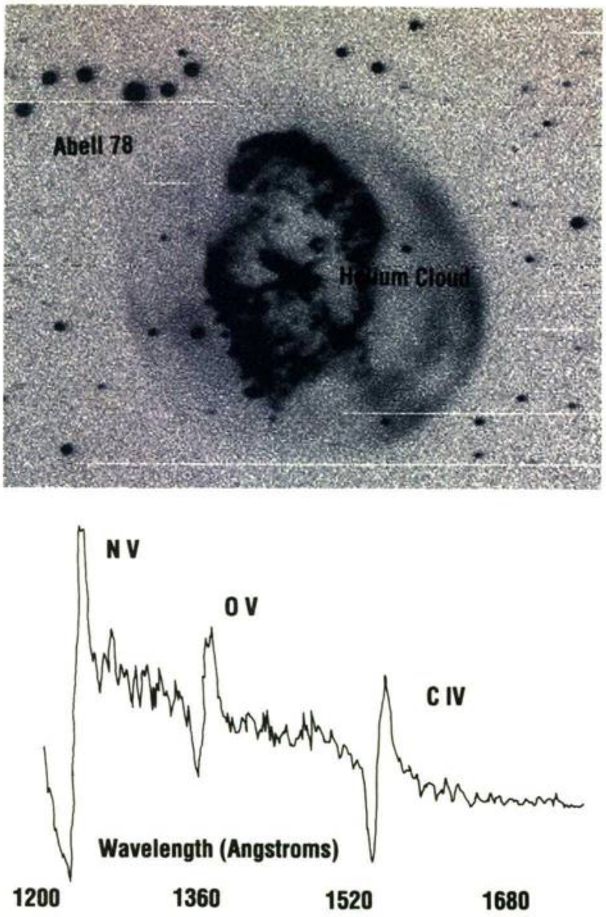
Because of the huge range of temperature and luminosity, astronomers expect, and get, an enormous range of spectral characteristics. We are obviously dealing not with just one kind of star but many. The brightest ones, those on the horizontal tracks of the H-R diagram, often (but, for reasons we do not understand, not always) possess strong winds that continue to blow mass from their surfaces. The consequent thinning of the stars' outer skins can strongly influence the nuclear burning that still goes on below and can probably affect the nature of the eventual white dwarf.

The winds can be studied by their spectral signatures, which vary according to the stars' temperatures. At the lower end we find extraordinary complexity, as illustrated by our observations of a star called Henize 2-99, found on the Circinus-Musca border deep in the southern sky. The remarkable array of oxygen, carbon, and helium emission lines are all produced by this star's outflowing gas. This star is of the Wolf-Rayet type, but it is *not* a Wolf-Rayet star. True Wolf-Rayet stars comprise a small group of very hot, luminous stars with an average mass of about 20 solar masses. They are evolved from massive O-type stars that have shed their outer skins, perhaps prior to becoming supernovae. They come in two varieties: carbon-rich (WC) and nitrogen-rich (WN). Many Wolf-Rayet stars even possess rings of dust and gas around them. Because the planetary counterparts mimic the behavior of the WC (there are no WN) Wolf-Rayet stars, they consequently share their name, but they should not be confused with the classical Wolf-Rayets.

Chemical analysis of a spectrum this complex is not yet possible. Nevertheless, astronomers can still use the lines to infer at least some of the stellar characteristics. For example, when satellite-borne telescopes are used to look at these stars at deep ultraviolet wavelengths, we commonly see odd-looking line features that consist of an emission line flanked on the shortward, or violet, edge by an absorption line. These are called P Cygni lines after the stellar prototype in the constellation Cygnus.

This curious spectrum is actually easy to explain. The emission lines arise from the low-density gas expanding around the star. However, the more rapidly expanding opaque gas between us and the star absorbs some of the starlight. Since the absorbing part of the gas is coming directly at us at a high velocity, the absorption feature is Doppler-shifted toward shorter wavelengths (the same phenomenon that makes the pitch of an approaching automobile horn sound higher).

By measuring the shortest absorbing wavelength, which corresponds to the fastest-moving material that is closest to our line of sight, the outflow velocity can be determined. Furthermore, by analyzing the strength



ABELL 78'S CENTRAL STAR, in a dense helium cloud, displays P Cygni lines, which are characteristic of an expanding envelope. NOAO photo courtesy G. H. Jacoby.

of the emission and absorption features, the rate at which the star is losing mass can also be derived.

The wind speeds seem to increase with temperature, running from a low of perhaps 1,000 kilometers per second around 30,000 K, which is still very high compared to the nebular expansion velocities, to as much as 4,000 kilometers per second near 100,000 K. A variety of research studies show that typical mass-loss rates are about one hundred millionth of a solar mass per year. The number is small compared to those derived from Mira stars of advanced age, which can be 1,000 times greater, but it is still some *million* times larger than what is lost annually by our placid Sun.

As we look toward higher temperatures, from the 30,000 to 40,000 K range of the planetary Wolf-Rayet stars, we see fascinating changes. The spectra are generally simpler and the ionization level changes in response to increased energy input from the star. Some hot stars have practically no wind features at all. But others at the high-temperature end of the scale show extraordinary lines of five-times ionized oxygen, or O VI. Some of these lines are enormously powerful. At the extreme, the principal O VI line at 3820 angstroms can by itself have a luminosity equal to that of our Sun! These rare "O VI stars" present a real puzzle because among them there is little correlation observed between line strength or wind velocity and other stellar parameters, such as temperature and luminosity. This is probably testimony to our own ignorance.

Astronomers do not yet understand what controls these winds or what turns them on and off. They do know, however, that the stellar winds finally die down. The low-luminosity stars, those that are descending the H-R diagram on their evolutionary paths toward the white dwarfs, display little more than absorption lines, as all normal stars do. But these stars can show some interesting behavior and their spectra are much easier to analyze. A few, like the central star of the Helix Nebula, are very deficient in helium while others are anomalously rich in it.

This separation of elements divides white dwarfs into two classes: DA (no helium in the spectrum) and DB (no hydrogen). In fact, unusual chemical compositions are evident in many different stars. The planetary Wolf-Rayet stars appear to be very rich in helium and carbon, for example, because the winds have stripped away the outer layers exposing the inner regions that have been changed by nuclear processing.

One of the oddest central stars known is the nucleus of a nebula called Abell 78. The star is surrounded by a small zone, buried within the larger planetary, that is almost pure helium. Astronomers think that when the star was nearing the end of its life as a planetary nucleus, at a time when it was fading and the large nebula was dissipating into space, the helium shell surrounding the spent carbon core suddenly fired up and began to burn. This event caused the star to expand again from white-dwarf size to giant proportions. During this expansion phase the resulting lower surface gravity enabled the star to strip itself of its remaining hydrogen skin (if it had any left at all by that time) to begin pumping out some of its by-then quiet helium underlayer. Thousands of years later the star has re-evolved as a planetary nucleus and we see the remnant of the helium wind closely enveloping it: a planetary inside a planetary.

A group of us have recently studied the central star of Abell 78 in some detail with the *International Ultraviolet Explorer* satellite. Its 80,000 K surface is still creating a wind that blows at the enormous speed of 3,700 kilometers per second. We can actually measure the manner in which the wind accelerates as the gas moves away from the star, and we can see absorption lines in the spectrum caused by the surrounding helium zone and its interaction with the fast wind. The mass-loss rate of roughly 2 billionths of a solar mass per year is fairly normal for these stars. We still do not understand the implications of this mass loss on the star's evolution, but it is certain to be important.

Eventually, detailed studies applied to a wide variety of planetary nuclei will solve many of the mysteries surrounding these enormously hot stars: how the winds operate, the way in which the unusual chemical compositions are generated, how fast the stars evolve, and so on. At last astronomers are beginning to witness the final state of stellar evolution. And the way is being illuminated by some of the heavens' loveliest objects, the planetary nebulae. ☐

James B. Kaler is a Professor of Astronomy at the University of Illinois at Champaign-Urbana. His research specialty is the evolution of planetary nebulae and their central stars. He is the author of Stars and Their Spectra, *(Cambridge University Press, 1989). A version of this article appeared in* L' Astronomia.

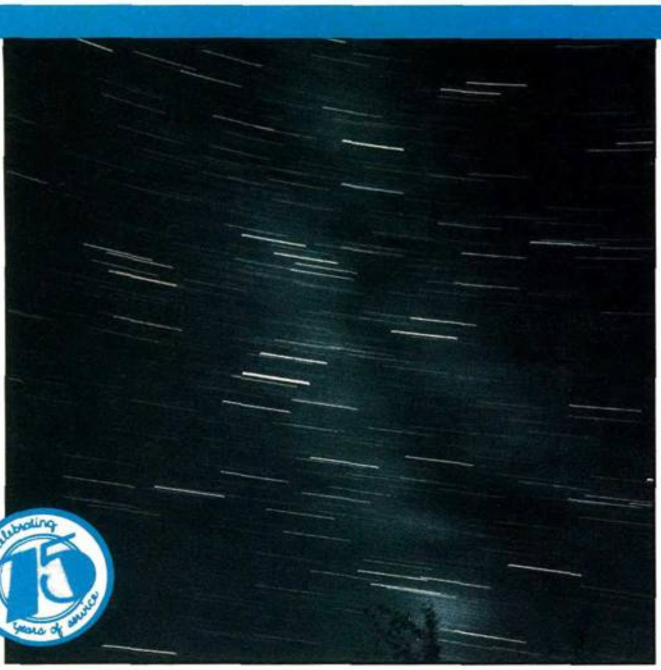


Photo by Michael Spano.

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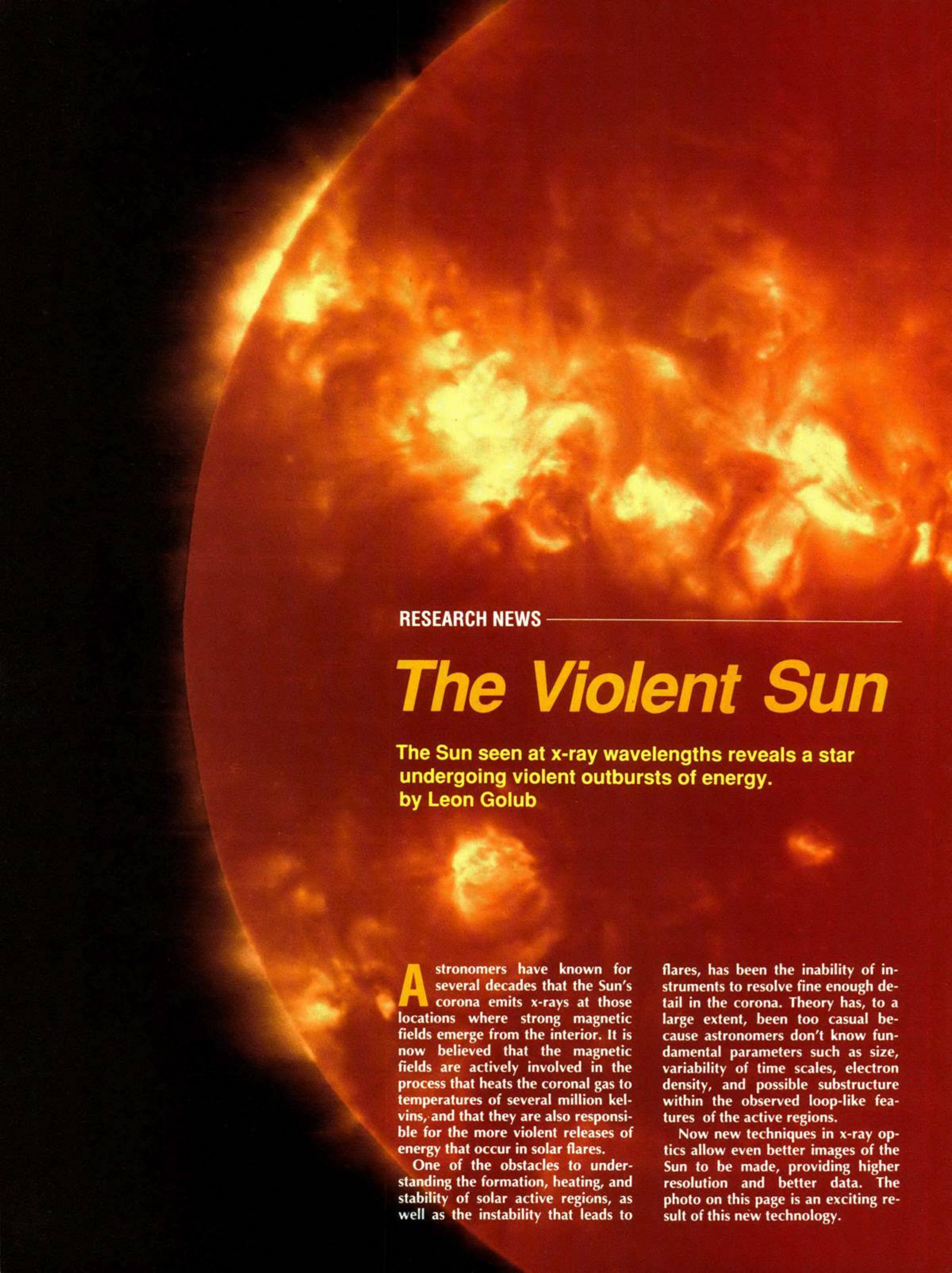


RESEARCH NEWS

The Violent Sun

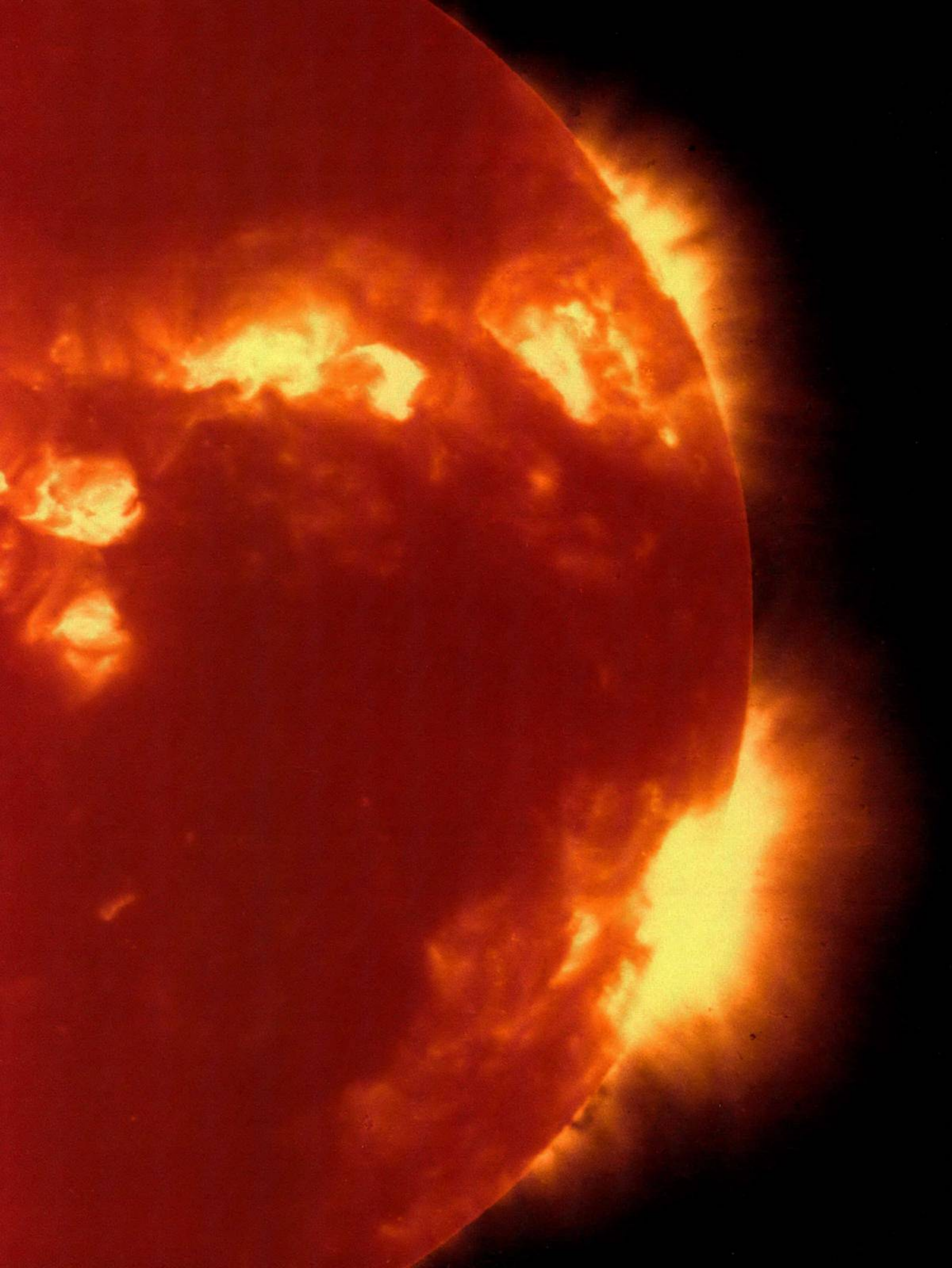
The Sun seen at x-ray wavelengths reveals a star undergoing violent outbursts of energy.

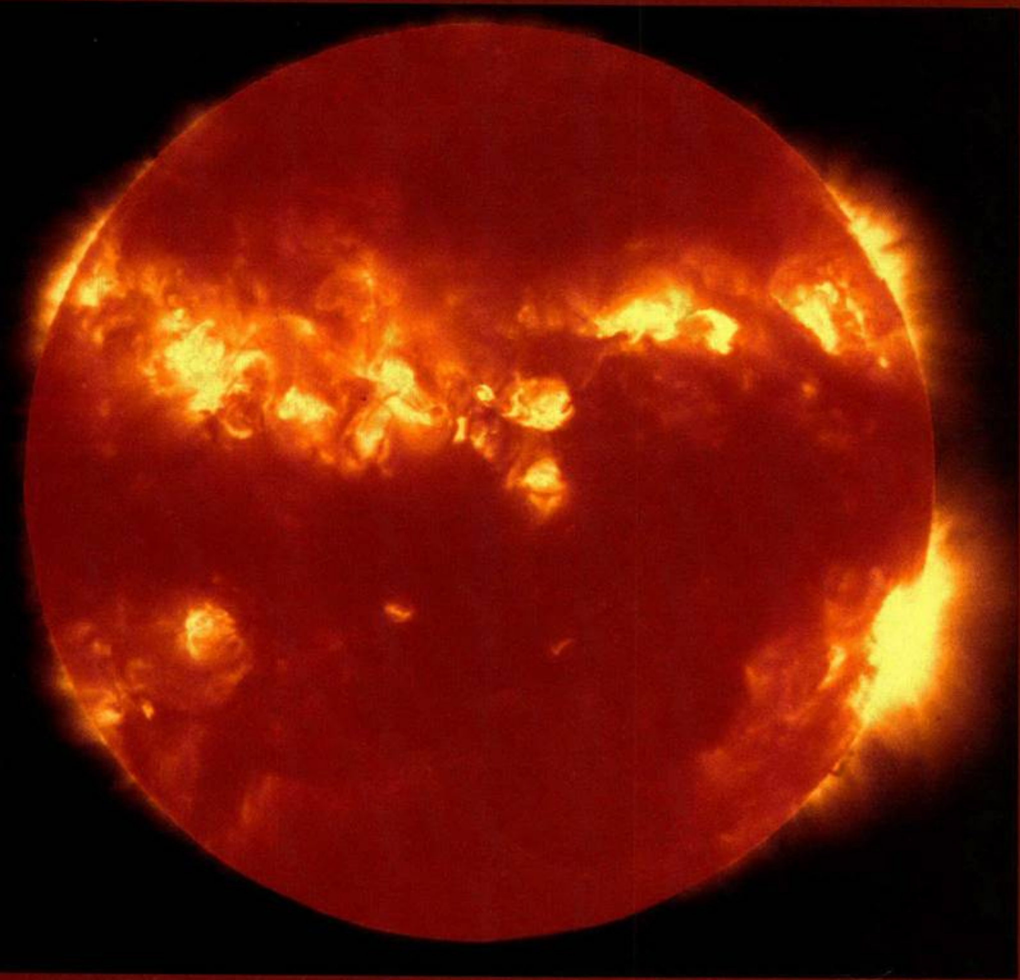
by Leon Golub

Astronomers have known for several decades that the Sun's corona emits x-rays at those locations where strong magnetic fields emerge from the interior. It is now believed that the magnetic fields are actively involved in the process that heats the coronal gas to temperatures of several million kelvins, and that they are also responsible for the more violent releases of energy that occur in solar flares.

One of the obstacles to understanding the formation, heating, and stability of solar active regions, as well as the instability that leads to flares, has been the inability of instruments to resolve fine enough detail in the corona. Theory has, to a large extent, been too casual because astronomers don't know fundamental parameters such as size, variability of time scales, electron density, and possible substructure within the observed loop-like features of the active regions.

Now new techniques in x-ray optics allow even better images of the Sun to be made, providing higher resolution and better data. The photo on this page is an exciting result of this new technology.





FINESCALE CORONAL STRUCTURES are seen in unprecedented detail in the iron XVI line at 63.5 angstroms, which is formed at 2 to 3 million kelvins. The false-color image has 3/4 arcsecond resolution. Courtesy IBM Research and the SAO.

The traditional method of focusing x-rays is to use a grazing-incidence telescope. X-rays are absorbed by the surface of a normal mirror unless the mirror is placed at an extremely shallow angle so that they bounce off, similar to a stone skipping over a quiet pond. By using a variety of cylindrical reflective surfaces, the x-rays can be focused.

Unfortunately, the method is not without its problems. Like any telescope mirror, the figure has to be very accurate. But the cylindrical shape of a grazing-incidence mirror makes figuring the mirror more difficult and therefore expensive.

It is now possible, however, to put a multilayer reflective coating onto the front surface of a figured and polished mirror that can reflect x-rays and bring them to a focus in the same manner as the mirror in a Newtonian telescope. An immediate advantage of this technique is that the figure quality and scattering properties of the mirror, and therefore the sharpness of the image, are substantially better than can be achieved with grazing-incidence telescopes. Such a telescope was used to make this image of the Sun.

On September 11, 1989, a NASA sounding rocket carried an x-ray telescope above Earth's atmosphere. The telescope's mirror was coated to reflect 63.5-angstrom x-rays, the location of an emission line in the solar spectrum formed at high coronal temperatures, which allows astronomers to study the active corona in unprecedented detail. The radiation emitted from the corona is limited primarily to a relatively small number of distinct emission lines formed by highly ionized atoms in the coronal gas. The choice of wavelength for the x-ray mirror's multilayer coating translates into a choice of spectral line, which in turn is equivalent to selecting a temperature for the image. The proper choice of temperature allows imaging of the extremely hot structures that make up the corona.

The photos reveal even more finescale structuring than had been predicted. The loop features seen in the bright emissions are very complex, reflecting the intricacy of the underlying magnetic field. It is also clear that these structures are just beginning to be resolved. Further improvements in resolution will reveal more detail. Presently, the observations place upper limits to the lateral scale size of coronal loops, which is a first step in restricting the set of existing theories.

As useful as these new images are, two additional steps are needed if astronomers are to make full use of the new imaging technique. First, the inherent limitation of the multilayer coatings (they work at only one wavelength) can be turned to advantage by constructing several telescopes, each tuned to a different portion of the solar spectrum. This permits spectroscopy at x-ray wavelengths so that the basic parameters of the hot plasma, such as temperature and electron density, can be determined. Such observations will also allow the disentangling of temperature changes from changes in the quantity of emitting material, a determination that is not possible with a single mirror tuned to a single spectral line.

It is equally important to carry out observations over an extended period to study evolving coronal structures. The only experiment to carry out high-resolution x-ray studies of the Sun over a long time period was the Apollo Telescope Mount on *Skylab*. This mission was extremely fruitful for solar physics.

The corona is a dynamic structure. Depending on the scientific objective, one must observe it for several hours to months or even years to learn how the magnetic fields evolve. Several missions involving the launch of high-resolution x-ray telescopes are presently planned or under consideration at NASA and the European Space Agency. Within the next decade we may begin to see major new results from this exciting technology. □

Leon Golub is a physicist at the Smithsonian Astrophysical Observatory and has been working in solar x-ray astronomy since 1973. The multilayer technique for soft x-rays was invented by Everhard Spiller of IBM in 1971. This x-ray imaging program is a collaboration between the SAO and the IBM Thomas J. Watson Research Center.

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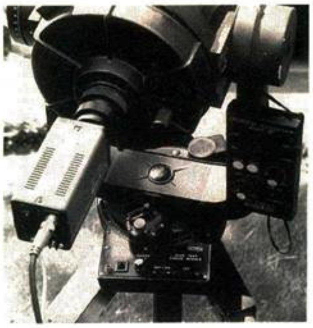

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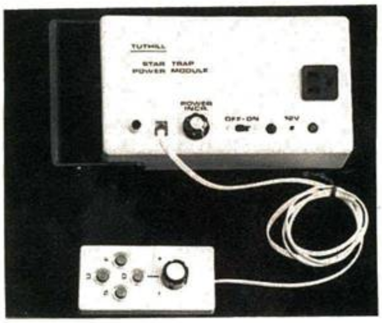

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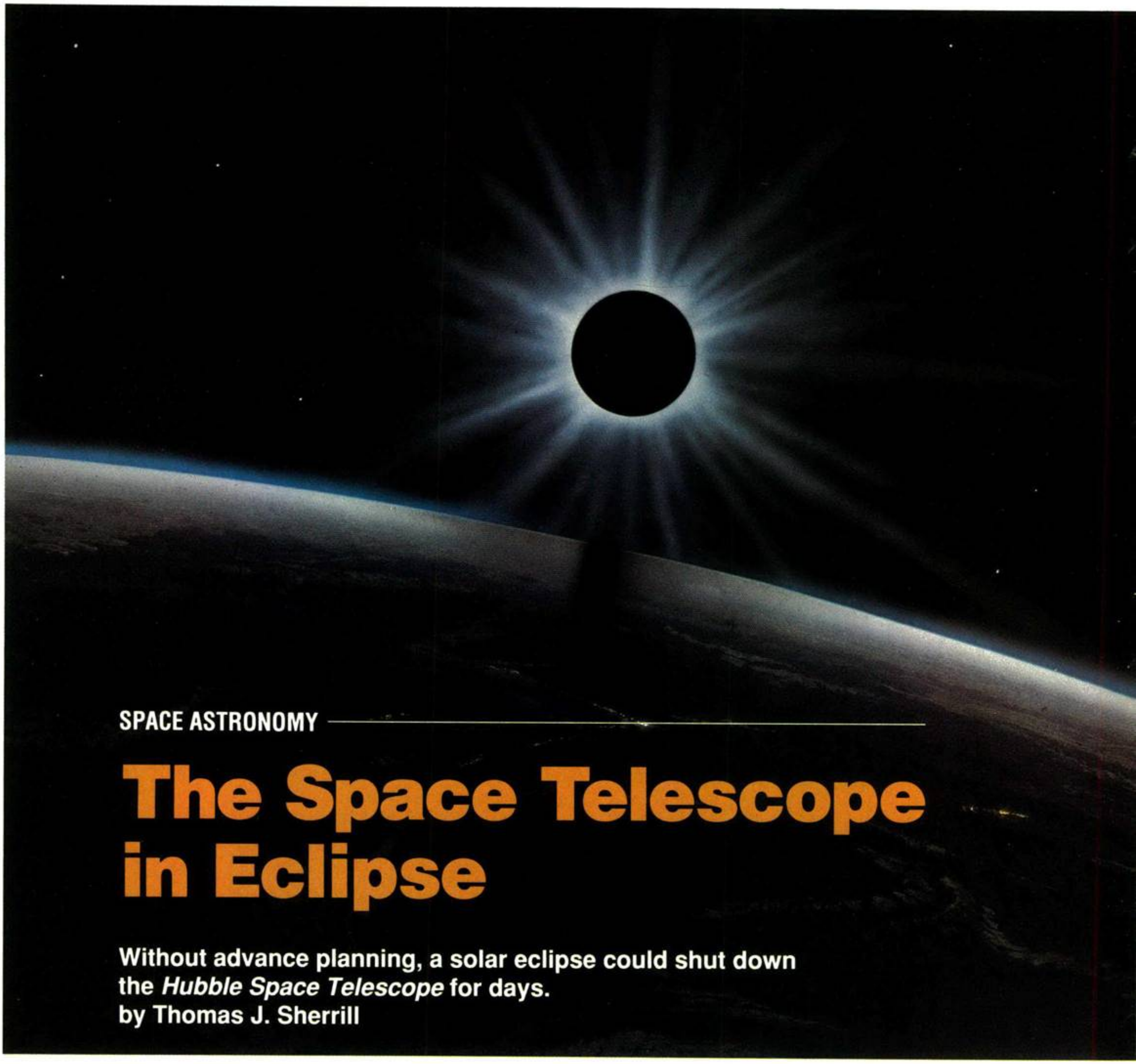


SPACE ASTRONOMY

The Space Telescope in Eclipse

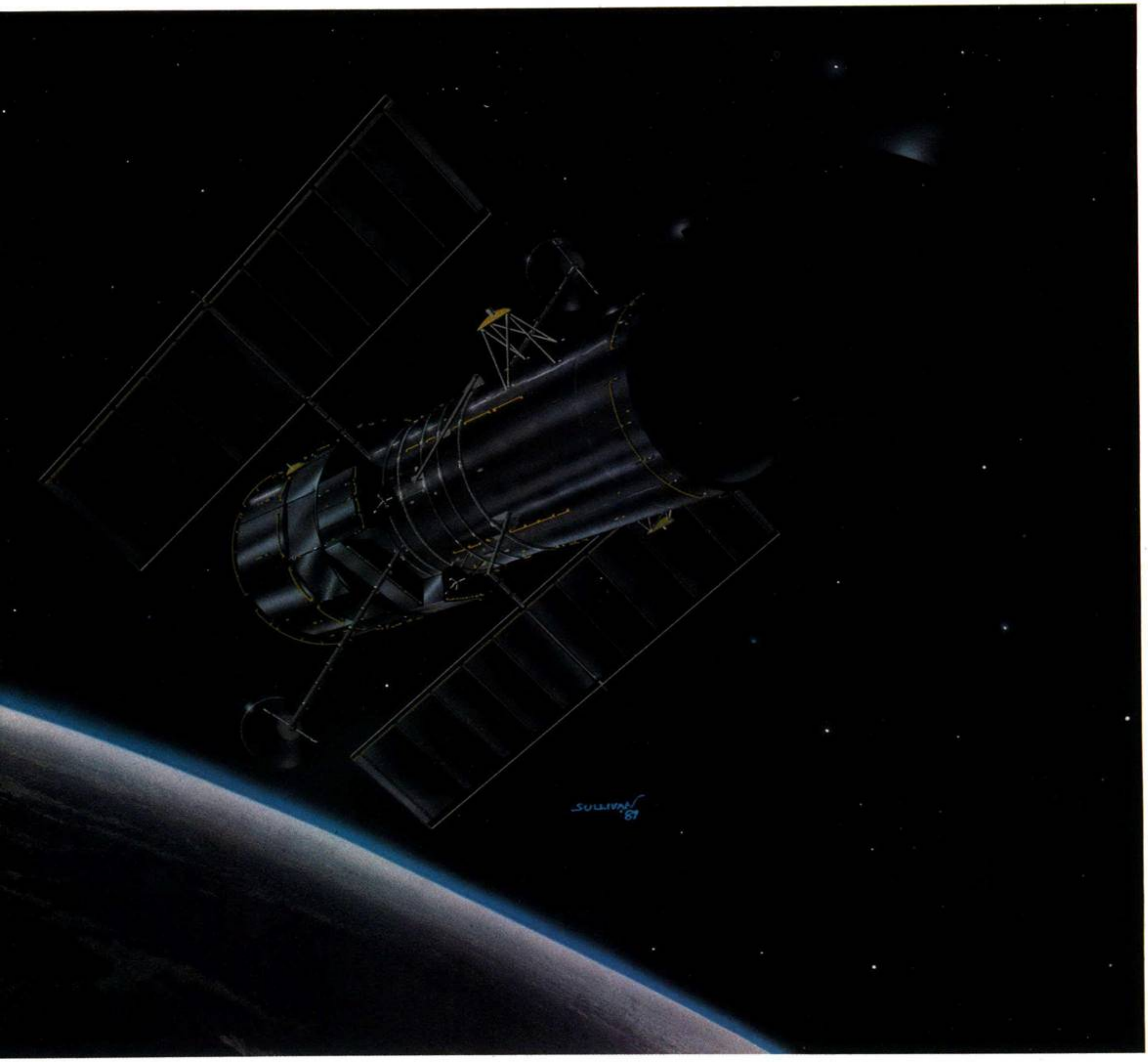
Without advance planning, a solar eclipse could shut down the *Hubble Space Telescope* for days.

by Thomas J. Sherrill

Not all scientists are thrilled by the approach of the July 11, 1991, total eclipse of the Sun, the longest total solar eclipse in the next 143 years. For astronomers and engineers associated with the operation of the *Hubble Space Telescope* (*HST*), the upcoming solar eclipse poses a significant problem: The loss of sunlight means the solar panels will generate less electricity for the spacecraft's electrical power system. Unless the spacecraft is warned ahead of time to expect the eclipse, the power loss could automatically trigger the spacecraft to shut itself down, and it might take several days for ground controllers to get *HST* operating again.

HST, along with the majority of other long-term Earth-orbiting satellites, derive their electrical power from large arrays of solar cells. These cells convert sunlight into the electricity needed to run the spacecraft's onboard instrumentation. Many spacecraft also carry batteries to store some of the electrical charge generated by the solar arrays for use while they are in Earth's shadow. (If a spacecraft's orbit is low enough and oriented so that it periodically passes through Earth's shadow, it is normally out of sunlight for 25 to 35 minutes in each 95- or 100-minute orbit.) These batteries see a seemingly endless cycle of daytime charging and nighttime discharging during their useful lifetimes, some fifteen times a day for the low orbits of these satellites. The spacecraft can get pretty used to having an hour or an hour and a quarter of sunshine to recharge its batteries, which is generally more than enough time to do the job.

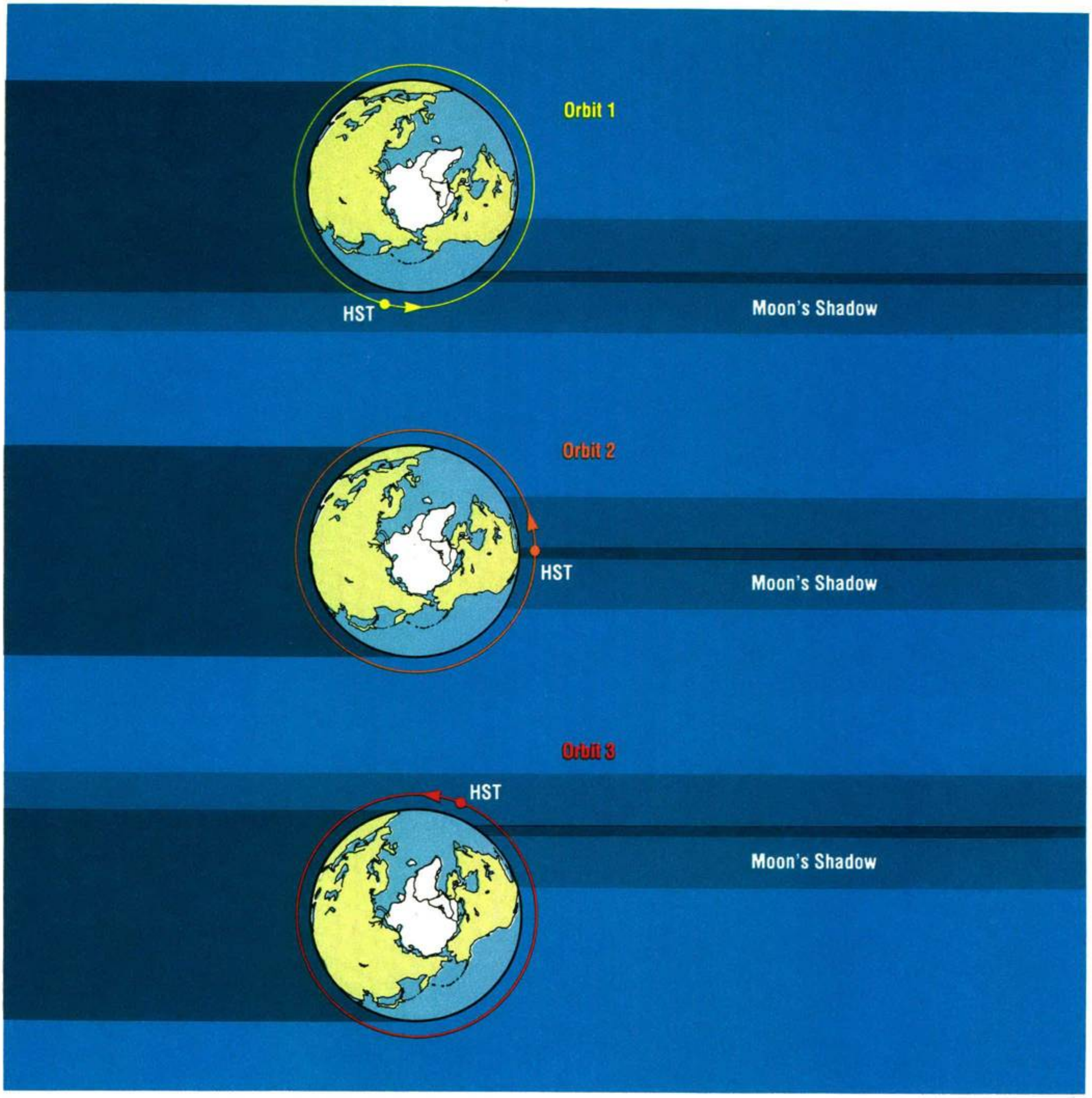
When the Moon's shadow interrupts this routine about every six months and eclipses up to 100 percent of the Sun's light for a period of time, it can create an unexpected drain on the spacecraft's electrical system. In the case of the summer 1991 eclipse, with its long



duration (almost 7 minutes of totality for Earth-based observers at maximum eclipse, which occurs near Baja California) and a track close to Earth's equator, the effect is about as great as possible. If ground controllers kept the spacecraft "in the dark" about an upcoming eclipse, the drain on its electrical system could have an impact on science operations.

Part of the reason for this "need-to-know" is that today's more sophisticated orbiting spacecraft are designed to have autonomous safemodes that protect the spacecraft from catastrophic failures in orbit. The spacecraft continually monitors the status of its onboard subsystems. Although most of the engineering data — temperatures, voltages, mechanism positions, and the like — are telemetered to the ground operational control center, the spacecraft's flight computer uses some of these data to check its own status. If a solar eclipse occurs for which the spacecraft had received no prior warning, these safemode checks might interpret a drop in battery charging current, for example, as a potential electrical system failure and command the spacecraft into a low-power "safe" configuration. In one of these modes the spacecraft would try to minimize the loss of power input by slewing so that the solar panels receive the maximum possible sunlight. This configuration uses only a minimal amount of electricity to prevent a further drain on the batteries until ground controllers can determine what caused the problem. But it also means that *HST* can no longer collect scientific data.

It can take anywhere from a few orbits to several days for the ground controllers to bring the spacecraft out of such a configuration. To avoid the loss of so much observing time, advance planners attempt to anticipate these situations and take steps to see that an eclipse does not inadvertently trigger the spacecraft's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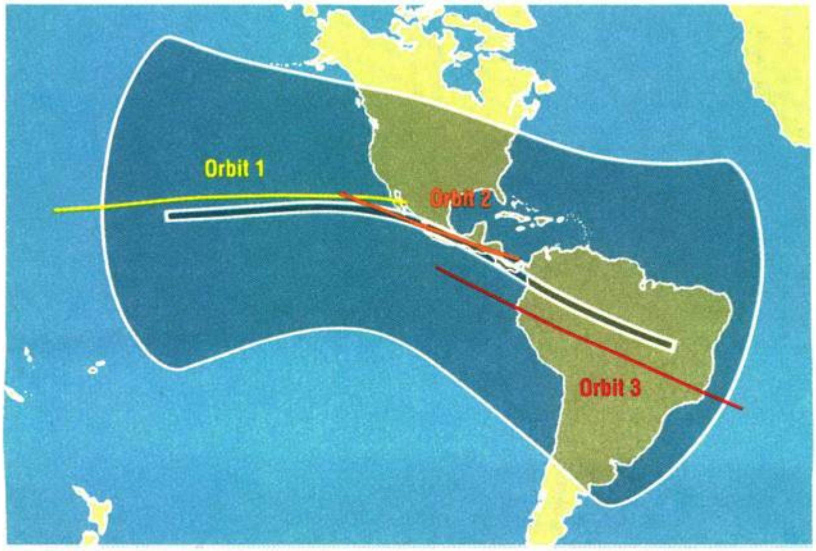
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Orbit 2
Orbit 3

IN A WORST-CASE SCENARIO for the July 1991 solar eclipse, *HST* is eclipsed during three consecutive orbits (above). In Orbit 1 *HST* emerges from behind the nightside of Earth and "sees" the eclipsed Sun. By Orbit 2 the Moon's shadow has moved eastward about halfway across Earth's surface while the spacecraft has orbited Earth one-and-a-quarter times. On Orbit 3 *HST* enters the Moon's shadow near sunset, some two-and-a-half orbits after the spacecraft was first eclipsed. As seen from the Moon's perspective (left), *HST* passes near the center of the Moon's shadow during each orbit.

safemodes. In many cases, this is done by resetting the limits at which the safemode kicks in — in effect reducing the sensitivity of the onboard "bells and whistles" — to values that take into account the loss of sunlight resulting from the Moon's obscuration of the Sun during the eclipse.

At orbital speeds of eight kilometers per second or so, it might seem that the spacecraft passes through the Moon's shadow too quickly for the eclipse to have much effect on the total amount of sunlight received. But this is not the case. Although the spacecraft quickly traverses the Moon's umbra (the central part of the Moon's shadow within which the solar eclipse appears total), it takes much longer to pass through the lunar penumbra, the area in which the Sun appears partially eclipsed. A satellite in low-Earth orbit crosses the under-300-kilometer-wide umbral cone in less than 40 seconds, but it can take as long as half an hour to cross the approximately 7,000-kilometer-diameter penumbral cone. The spacecraft needs to know beforehand how much sunlight will be falling on its solar arrays during this time.

The NASA center most involved with the orbital operations of scientific spacecraft is Goddard Space Flight Center in Greenbelt, Maryland. For years Goddard engineers have been simulating the response of onboard electrical power systems to solar eclipses. Harry Wajsgras, a power system manager at Goddard, has helped develop procedures for dealing with the problem on the *Copernicus* (*Orbiting Astronomical Observatory-C*) and *Solar Maximum Mission* spacecraft. When computer software flags an upcoming eclipse, Goddard support personnel use the most current orbital tracking data to generate a more accurate prediction of what the event will look like from orbit. By one week prior to the eclipse, Goddard completes an evaluation of the eclipse's impact on the spacecraft, adjusts the spacecraft's safemode limits to values appropriate for the predicted shadow conditions, and generates a preliminary timeline detailing spacecraft operations during the eclipse. A final timeline is delivered and final command verifications are performed one day prior to the eclipse.

The Impact on *HST*

As Goddard's power system manager for *HST*, Wajsgras requested that Lockheed (the systems engineering contractor) look into the impact of solar eclipses on the telescope's safemodes. Unlike the *Dynamics Explorer* spacecraft, which circles Earth in a fairly high-inclination orbit, *HST* will see only eclipses that are visible from the ground. Thus, Lockheed only had to examine those solar eclipses that could be seen from Earth and that are documented by, for example, the U. S. Naval Observatory. They then ran computer simulations of the ten solar eclipses that occur during the first five years following the telescope's scheduled launch in March 1990. Using these simulations, the computer sought for each eclipse the "worst case" orbital encounter among the large number of possible spacecraft orbital configurations. Several different criteria were used to define the worst cases.

One of the criteria used to measure the impact of solar eclipses on *HST* was a quantity equivalent to the amount of "full sunlight time" lost. For example, if an eclipse proceeds linearly from 0 percent to 100 percent of totality in 9 minutes and then linearly decreases to 0 percent in 9 more minutes, the lost sunlight time is 9 minutes: 18 minutes at an average of 50 percent of totality. This means that a complete day-side orbital passage of 60 minutes would yield only 51 minutes of full-sunlight battery charging time.

The impact of an eclipse on the power output of *HST*'s solar arrays is greater the longer the eclipse lasts and the "deeper" the eclipse appears as seen from the spacecraft. These factors, in turn, depend on how centrally the Moon's shadow cone passes over Earth's surface and how close *HST*'s orbital track passes to the center of this cone. In their 1966 book *Canon of Solar Eclipses*, Jean Meeus and his coauthors define a quantity "gamma" as a measure of an eclipse's degree of centralness. Gamma is defined as the minimum distance the axis of the Moon's shadow cone passes from the center of Earth, expressed in Earth radii. For the July 11, 1991, total eclipse, the value of gamma is –0.004 Earth radii (the minus sign indicates that the axis of the shadow cone passes south of Earth's center). This is the smallest absolute value for gamma in the next 324 years. Therefore, the 1991 eclipse, the third one *HST* could encounter if it is launched before mid-July 1990, serves nicely as a worst-case event.

The View from Orbit

The worst-case orbital track for *HST* occurs when the spacecraft passes through the Moon's shadow on several consecutive orbits. The Moon's shadow moves west to east across Earth's surface except for some of the relatively small number of eclipses that track close to Earth's poles. The shadow's speed is such that the center of the shadow cone can take as long as 4 hours to travel from one limb of Earth to the opposite limb. Because *HST* completes about two and a half orbits every 4 hours, it can actually be eclipsed during three successive orbits (see page 38). In this case *HST* moves toward the Sun and Moon in orbit 1, away from them in orbit 3, and in the same direction as the Moon's shadow during orbit 2, greatly prolonging the time *HST* spends in the shadow. If, in addition, *HST* passes near the center of the shadow cone on orbit 2 and both the Sun and Moon lie in the plane of *HST*'s orbit, the spacecraft's solar panels suffer their greatest loss of sunlight.

For the July 11, 1991, eclipse, the computer simulations showed that there were a range of *HST* orbit orientations for which the three-eclipse case occurs. In the worst such case a total of almost 32 minutes of full sunlight time is lost over the three orbits. The maximum degree of eclipse totality is 67 percent on the first orbit, 83 percent on the second orbit, and 95 percent on the third orbit.

Five Years of Eclipses

The table on page 40 summarizes the impact on *HST*, in both the best- and worst-case scenarios, of the first ten eclipses it should experience. The July 1991 eclipse has by far the greatest potential impact in terms of lost sunlight time, 9 minutes more than the 23-minute total found for the January 4, 1992, eclipse, which is the next worst case. In any one orbit the maximum lost sunlight time for any eclipse is about 18 minutes. *HST* also spends 70 minutes in the lunar penumbra during the July 11, 1991, eclipse, which is close to the maximum amount of time possible, although during half of the eclipses *HST* is in the shadow for an hour or more. In addition, each of these five cen-

Best- and Worst-Case HST Eclipse Scenarios

Date	Type	Gamma	Minimum Time in Shadow	Minimum Lost Sunlight Time	Most Orbits	Maximum Time in Shadow	Maximum Lost Sunlight Time
July 22, 1990	Total	+0.759	0	0	3	40	16
Jan. 15, 1991	Annular	−0.273	19	2	4	71	22
July 11, 1991	Total	−0.004	9	0.3	3	70	32
Jan. 4, 1992	Annular	+0.409	21	0.2	4	70	23
June 30, 1992	Total	−0.751	0	0	3	44	16
Dec. 24, 1992	Partial	+1.071	0	0	2	22	2
May 21, 1993	Partial	+1.137	0	0	1	6	0.2
Nov. 13, 1993	Partial	−1.041	0	0	2	15	3
May 10, 1994	Annular	+0.407	18	3	4	68	21
Nov. 3, 1994	Total	−0.352	11	0.2	3	59	21

Gamma: Minimum distance of Moon's shadow cone from Earth's center, in Earth radii. **Minimum/Maximum Time in Shadow:** Out of all possible orbital configurations, the least/most number of minutes *HST* can spend in eclipse. **Minimum/Maximum Lost Sunlight Time:** Least/most number of minutes of "full sunlight time" lost. **Most Orbits:** Maximum number of orbits in which HST can be eclipsed.

tral eclipses shows a potential Moon shadow time of 32 or 33 minutes during a single orbit.

The table also shows that the three annular eclipses in the first five years of *HST*'s operation present the possibility of four orbital eclipse events. An annular eclipse is one in which the apparent size of the Moon is smaller than that of the Sun, and thus at maximum eclipse a thin ring, or annulus, of the Sun remains visible around the Moon. This can only happen when the Moon is nearly at its farthest point from Earth in its orbit. Because of the Moon's greater than normal distance, its apparent displacement as seen from each end of an *HST* orbit is smaller than normal and its orbital motion around Earth is slower than normal. Thus, the track of the Moon across the sky is more compact and there is more time for eclipse events to occur. Because the first- and fourth-orbit eclipses are very shallow in these cases, the total lost sunlight time is generally less than 20 minutes.

For every eclipse having a gamma less than about 0.8 Earth radii (absolute value), there is at least one possible *HST* orbit in which the spacecraft experiences a total eclipse. Seven out of the first ten eclipses fall into this category.

The best cases listed in the table show that for each eclipse there are some *HST* orbit orientations that produce little or no impact on spacecraft operations. The most benign situation occurs when the Moon's shadow falls so far north or south of Earth that very few of the possible *HST* orbit tracks intersect it. Even in those cases where the eclipse is unavoidable (five of the ten events listed in the table), the total lost sunlight time never exceeds about 3 minutes.

HST Power Considerations

The question of whether *HST* would have enough power to perform its science mission has long been of concern to Marshall Space Flight Center, the NASA center that has overseen the building of the telescope. The picture has improved during the past few years, however. The original solar arrays have been replaced by their European suppliers with advanced, more efficient solar cell blankets that generate about 10 percent more power than the old arrays. A more important step taken recently was the upgrading of the onboard power storage capability. Originally *HST* was equipped with nickel-cadmium batteries to store the electricity generated by the solar arrays. Just last November, however, project managers approved the use of new and more powerful nickel-hydrogen batteries.

Computer simulations show that if the nickel-cadmium batteries had been used, one onboard safemode check that uses total battery charge as a monitor could signal the spacecraft to enter safemode during a worst-case, single-orbit eclipse. As indicated earlier, mission planners would have forestalled such a safemode entry by resetting the threshold values used in the onboard test a short time before the eclipse.

Luckily, the above worst-case scenario presents no problem for the safemode total battery charge test with the new nickel-hydrogen batteries because these batteries can hold about half again as much charge as the nickel-cadmium batteries. However, even with the nickel-hydrogen batteries, a more stringent safemode check based on the amount of current used to charge the batteries would probably fail even during a fairly shallow eclipse for some of *HST*'s orbital configurations. Mission planners will use computer models to estimate what charging current can be expected during a given eclipse and then reset the safemode threshold values.

It is obviously just a coincidence that close to the worst of all possible solar eclipses — from a spacecraft power system standpoint — occurs less than a year and a half after the launch of *HST*. But with only a modest amount of advance planning, mission planners will be able to program *HST*'s flight computers so that the telescope can take the extra minutes of darkness in stride. Then the *HST* scientists can feel free to sit back in Hawaii or Baja California and enjoy the eclipse with all the other professional and amateur astronomers. □

Thomas J. Sherrill is an astronomer who has been working on the Hubble Space Telescope *project at Lockheed for the past seventeen years. He was responsible for the* HST *Design Reference Mission, a sample thirty-day astronomy mission schedule used as a benchmark for system design.*

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Into the Night Between the Stars

The *Voyager* mission didn't end at Neptune. The spacecraft is now seeking the boundary where the Sun's realm gives way to the Galaxy's.

by D. Venkatesan and S. M. Krimigis

With the Neptune encounter over, the *Voyager* project has entered its final phase. After blazing a trail across the solar system, *Voyagers 1* and *2*, together with forerunners *Pioneers 10* and *11*, are now heading away from the Sun on escape trajectories, never to return. These four spacecraft have become mankind's first interstellar probes.

It is true that the power supplies on board each will fail long before the probes have covered even one percent of the distance to the nearest star. But scientists have hopes that at least one of the craft — *Voyager 1* — will cross a yet-undetected boundary into a new and unmapped region of the solar system before its dwindling supply of electrical power gives out sometime around 2020. This mysterious region is called the heliopause and it marks the boundary where the Sun's magnetic domain yields to that of the interstellar medium and the Galaxy at large.

To understand why astrophysicists are eager to find the heliopause, we must begin not with *Voyager* gliding through the icy twilight five light-hours from the Sun, but with the Sun itself. From the Sun's seething photosphere, its visible surface and the lowest part of its atmosphere, charged particles (electrons and protons) are hurled outward in a mighty, supersonic hurricane of plasma that astrophysicists call the solar wind.

The solar wind is a normally invisible flow of charged particles. Yet where the wind lies closest to the Sun and is densest, it can be seen briefly during a total solar eclipse as the pearly white, streaky corona that surrounds the black disk of the Moon. Changing slowly over days, months, and years, the shape of the corona is determined by long- and short-term variations in the solar magnetic field and solar wind.

For reasons that astrophysicists don't fully understand, the corona is far hotter than the photosphere immediately below. Whereas the solar surface has a temperature of about 6000 kelvins, the corona is at 1 to 2 million kelvins. The gas leaving the corona expands as it escapes, generating the flow called the solar wind. This tears through interplanetary space at supersonic speeds of 400 to 600 kilometers per second.

Voyager 1 is likely to be the first manmade craft to reach interstellar space.

The solar wind doesn't blow evenly or steadily. It varies over time and it also shows a systematic increase in velocity from the solar equator to the higher latitudes, where regions known as coronal holes have frequently been observed. Coronal holes occur when the structure of the Sun's magnetic field allows the solar wind to escape more easily and quickly than in the rest of the corona.

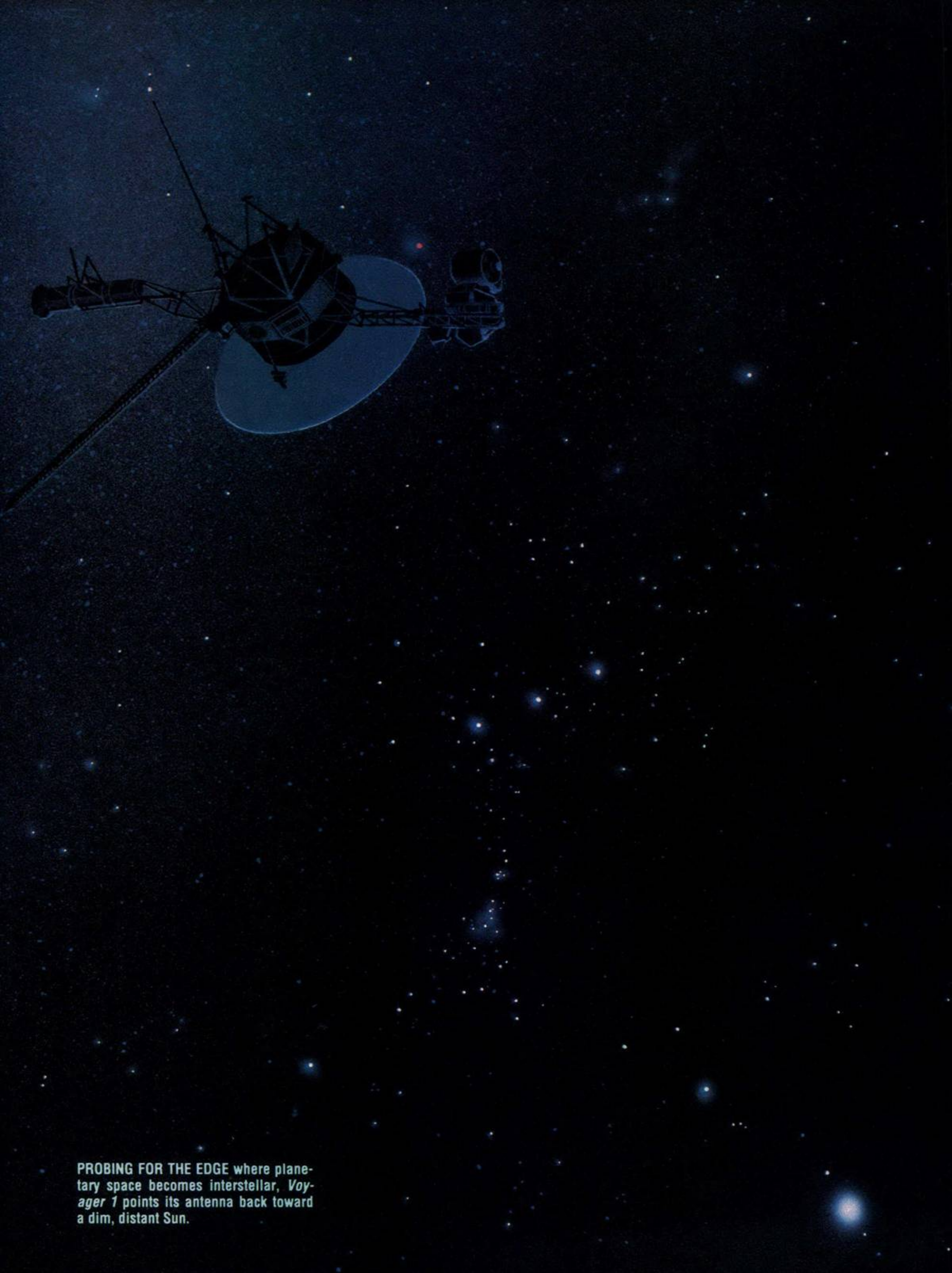
Eruptions on the Sun's surface known as flares can also create brief gusts of high-velocity particles in the solar wind. On occasion, speeds up to 2,000 kilometers per second have been observed. As the Sun approaches its period of maximum activity for this cycle, flares are becoming more common. Massive flares occurred in March, September, and October of last year, for example. When the turbulent gusts of particles from flares reach Earth they can initiate magnetic storms that disrupt long-distance communications and generate eerily beautiful auroras in both hemispheres.

The solar wind doesn't stop at Earth, of course. After sweeping past our planet it continues outward through the solar system. Eventually, when much reduced in strength, the wind reaches the limit of the Sun's magnetic realm, one or two hundred astronomical units out from Earth. (One astronomical unit is the distance between Earth and the Sun, or 150 million kilometers.) Yet even here, where sunlight is only as bright as twenty Full Moons, astrophysicists can still track the influence of the wind's particle storms by their effects on cosmic rays.

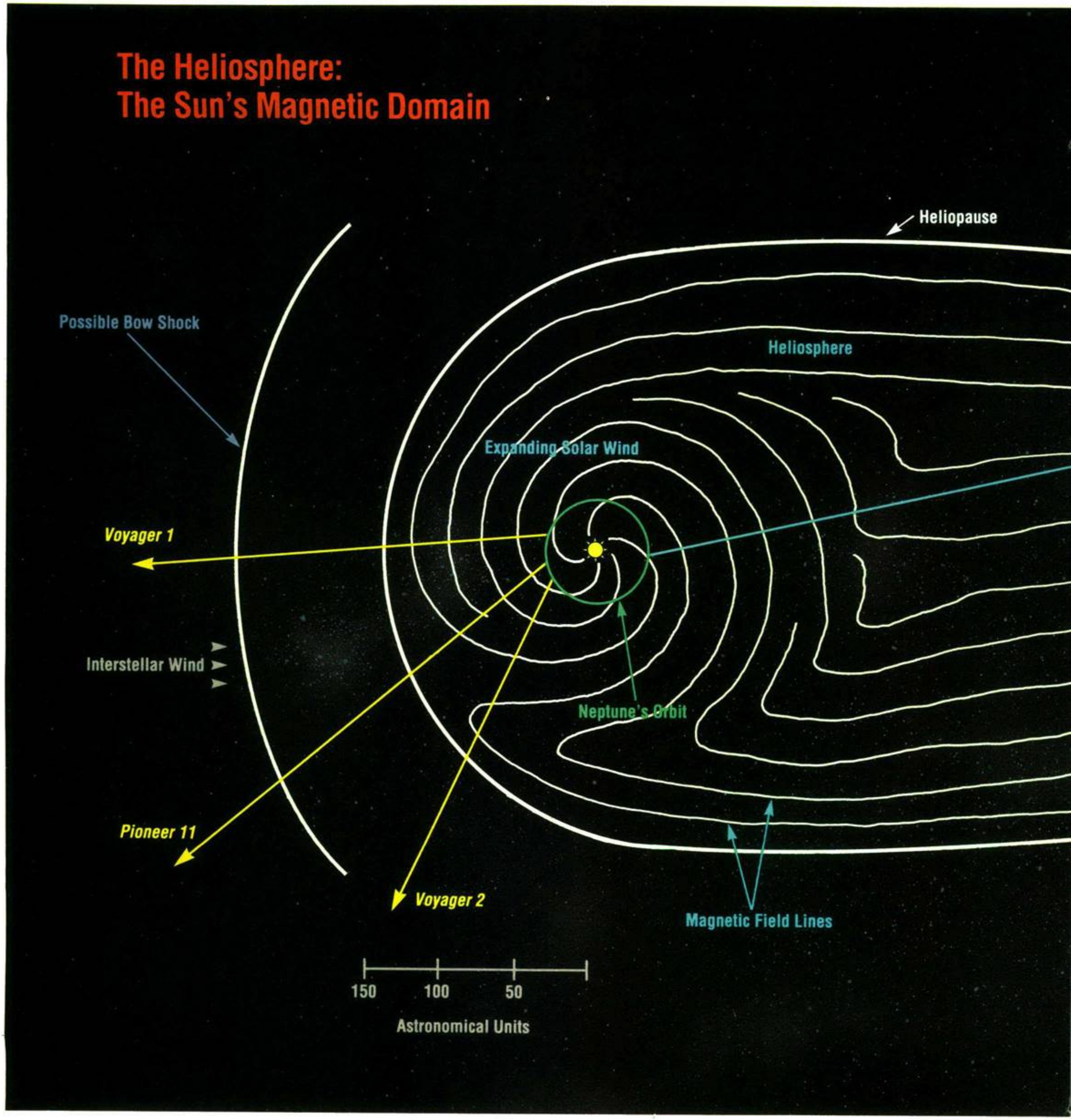
The expansion of the solar wind combines with the Sun's rotation to produce two effects. First, the solar plasma tends to flow out to form a sheet roughly in the plane of the solar equator. Second, the solar magnetic field is stretched like taffy. While one end remains firmly rooted in the solar photosphere, the other end is embedded in the plasma that is streaming radially outward.

For a distance the magnetic field lines run out radially. But even before the field lines have crossed the orbit of Mercury, the Sun's rotation has started to bend the radial pattern into a spiral, making the whole structure resemble the streams of water from a spinning garden sprinkler. By the time the field lines reach the orbit of Jupiter, they are lying nearly crosswise to a line drawn between Jupiter and the Sun.

When the solar wind blows past the planets, it "senses" them as obstacles in its way and flows around them, creating a cavity in a planet's wake. If a planet has a magnetic field, the solar wind will first encounter the planet's bow shock, a kind of sonic boom created where the supersonic wind slows to subsonic speeds. The distance the bow shock and the magnetopause directly behind it lie from the planet is



PROBING FOR THE EDGE where planetary space becomes interstellar, *Voyager 1* points its antenna back toward a dim, distant Sun.



The Heliosphere:
The Sun's Magnetic Domain

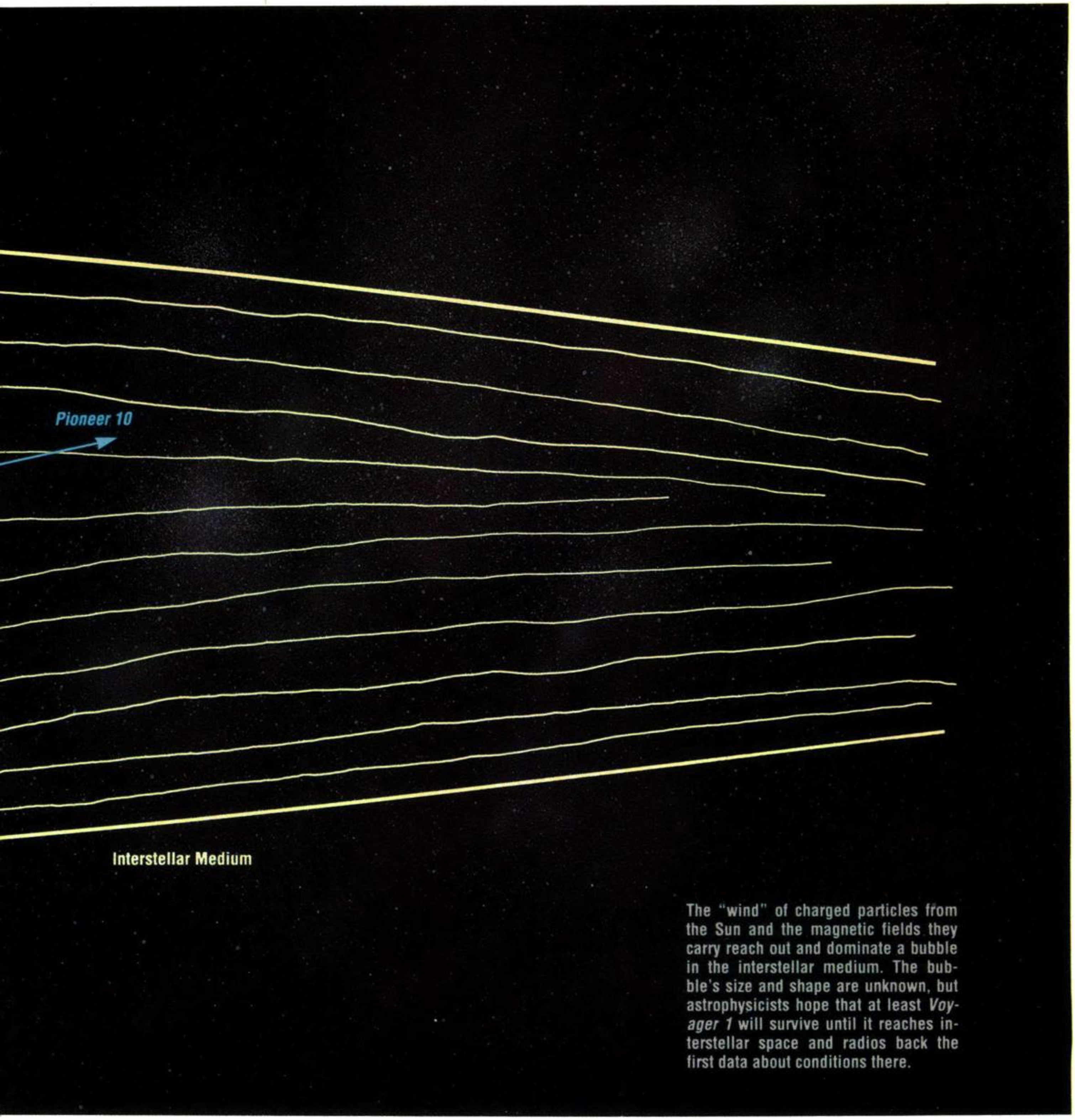
Heliopause
Possible Bow Shock
Heliosphere
Expanding Solar Wind
Voyager 1
Interstellar Wind
Neptune's Orbit
Pioneer 11
Voyager 2
Magnetic Field Lines
150
100
50
Astronomical Units

determined by the strength of the planet's magnetic field relative to the on-rushing solar wind. At times of high solar activity the wind pushes more strongly and the planetary field is compressed. When the solar wind pressure drops, the planet's magnetic domain expands accordingly.

In just the same manner the Sun's magnetosphere — the heliosphere — is controlled and shaped by the interaction between the solar wind and the flow of particles in the Galaxy's interstellar medium. The heliosphere therefore is the region around the Sun where solar activity dominates. Within this region, physical conditions are established, modified, and governed by the Sun.

Although Earth orbits within the heliosphere and space probes have flown through its inner parts for decades, astrophysicists still have many unanswered questions about the heliosphere. What is its overall morphology? How does it evolve in space and time? How far into the interstellar medium does its influence extend? No one knows. Nor can anyone say what it might look like from the outside or describe in detail what conditions are like in space beyond it.

While the conceptual picture of the heliosphere looks pretty murky, astrophysicists have nonetheless de-

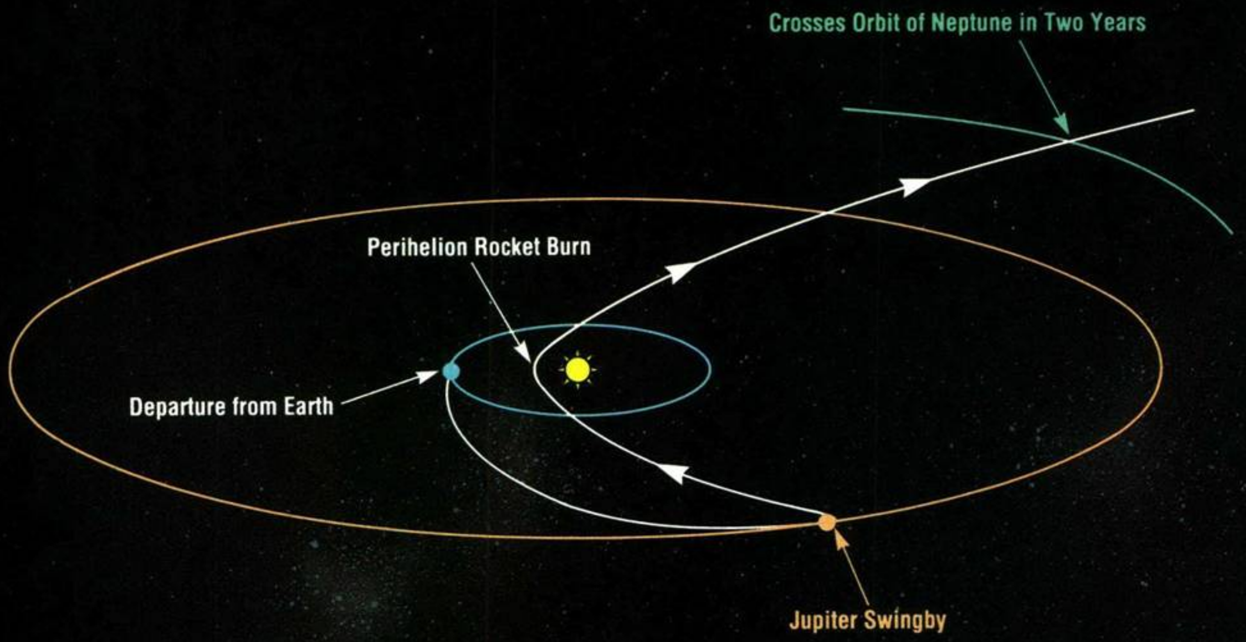


The "wind" of charged particles from the Sun and the magnetic fields they carry reach out and dominate a bubble in the interstellar medium. The bubble's size and shape are unknown, but astrophysicists hope that at least *Voyager 1* will survive until it reaches interstellar space and radios back the first data about conditions there.

duced some of its properties from indirect evidence. For example, the heliosphere was once assumed to be spherical in shape. However, by studying the space motions of nearby stars astronomers learned that the local interstellar medium flows past the Sun from the general direction of the galactic center with a velocity of about 20 kilometers per second. This discovery altered the picture considerably. Given the interstellar medium's low density, scientists believe that 20 kilometers per second is fast enough to generate a bow shock on the upstream side. Another effect of the interstellar wind will be to pull out a long magnetotail in the direction of the flow like a plume of smoke from a chimney.

The region between the boundary of the heliosphere (or heliopause) and the bow shock contains the interstellar magnetic field, which has a strength of one or two millionths of a gauss. (A compass on Earth swings under the influence of a third of a gauss.) Inside the region of the shock front the magnetic field coming from the distant Sun follows the spiral pattern, while the plasma outflow in the solar wind streams radially. Outside the shock front the magnetic fields are disordered and the plasma flows turbulently as it is buffeted by the interstellar flow.

The Interstellar Probe: A Fast Trip to the Edge



The high-speed *Interstellar Probe* mission, proposed for launch in 2000, would leave the heliosphere in about six years — half the time it took *Voyager 2* to get only as far as Neptune.

Just how far upstream from the Sun the heliopause lies is not known. Current conjecture places it between 100 and 150 astronomical units away. The distance to the heliopause on the downstream side is even more of a mystery, but an educated guess puts it at 10,000 AU, or about one sixth of a light-year.

Much useful information about the heliosphere and the interstellar medium has come from studies of cosmic rays, the high-energy charged particles that arrive at Earth in essentially equal amounts from all directions. While some cosmic rays come from the Sun, most are galactic in origin.

About fifty years of study has shown that cosmic-ray intensities systematically vary and this variation follows closely the 11-year sunspot cycle that tracks solar activity. When solar activity is high, fewer cosmic rays arrive; when the Sun is quieter, cosmic rays are more abundant. But the cosmic ray variations do not follow precisely in step with the Sun's changing activity. Instead, nine months to a year elapse between the time of highest solar activity and the weakest cosmic ray activity. The same delay has been seen to occur between the time sunspots reach a minimum and cosmic rays become most abundant.

What is happening? During periods of maximum solar activity the Sun's magnetic field encompasses a greater volume of space. The extended magnetic field absorbs more galactic cosmic rays and thereby decreases the number seen. The inverse occurs in years of lowest activity.

However, the heliosphere's expansion doesn't take place instantly; it takes time for the field to grow to maximum size. If the solar wind flows at about 500 kilometers per second, it will travel one astronomical unit in 3.3 days. Therefore, the nine- to twelve-month delay between the two maxima translates into a heliospheric size of 80 to 110 astronomical units.

Galactic cosmic rays are the most common, but some originate in the Sun or within the heliosphere itself. The heliosphere is not simply a passive medium with energetic particles injected at its center (solar cosmic rays) or seeping in across its outer boundary (galactic cosmic rays). In reality it is a dynamic region continually responding to changes in the two cosmic ray sources and, in turn, modifying them. The solar wind itself can create new energetic particles: in supersonic interactions at planetary bow shocks, in traveling interplanetary shocks, in regions where slow and fast solar streams interact, and even out at the heliopause itself where the supersonic solar wind becomes subsonic as it encounters the interstellar medium.

Cosmic rays thus serve two functions simultaneously. They provide astrophysicists with a coarse measure of the heliosphere's size and their variable intensity reflects the state of the heliosphere and the changes occurring within it. These changes may be driven by solar variations and by interactions at planetary bow shocks. Because the heliosphere is continuously evolving, systematically tracking how cosmic-ray intensities vary in space and time will let astrophysicists study the heliosphere in all its vastness and complexity.

What does the heliosphere look like? The diagram on pages 44 and 45 shows a schematic view of it with the four probes on escape trajectories going off in their diverging directions. *Voyager 1* is headed most nearly upstream and will probably encounter the heliopause first. *Pioneer 11,* also going upstream, has been on its way longer but is traveling more slowly. *Voyager 2* has farther to go to reach the heliopause and its power supply will likely give out before the probe crosses the boundary. *Pioneer 10* is heading down the long magnetotail behind the Sun, more or less directly away from the other three craft, and will probably be long dead by the time it exits the heliosphere.

At present *Pioneers 10* and *11* are 47 astronomical units and 29 AU from the Sun, and *Voyagers 1* and *2* are 38 AU and 30 AU away. *Voyager 1* is heading outward at 35° north solar latitude. After its encounter with Neptune, *Voyager 2* is proceeding toward 48° south solar latitude. The *Pioneers* are traveling generally close to the plane of the solar equator.

Over the past seventeen years these spacecraft have enabled astronomers to survey cosmic-ray intensities from the orbit of Earth out to nearly 50 AU. Cosmic-ray intensity increases at the rate of about 2 to 4 percent per AU. This means that the cosmic-ray intensity at 50 AU is about three times greater than at Earth.

However, due to solar cycle activity the cosmic-ray intensity at Earth has been varying considerably since the launch of both the *Pioneer* and *Voyager* spacecraft. What is needed to measure the true variation of cosmic-ray intensity with distance from the Sun is a probe that flies from Earth to outside the Sun's realm in a time that is short compared to the 11-year solar cycle. Such a probe could measure more accurately the varying intensity of cosmic rays as it traversed the Sun's magnetosphere quickly enough to minimize the complications due to the changes in solar activity. What's really needed, therefore, is a "snapshot" that shows the shape of the heliosphere as close to instantaneously as possible.

The Interstellar Probe will reach Neptune's orbit in less than two years — a journey that took Voyager 2 twelve years.

A potential space mission that promises to obtain measurements like this has recently been proposed. This *Interstellar Probe* spacecraft would fly out to Jupiter and use the planet's gravity to redirect the craft back toward the Sun on a high-velocity course that would skim about two million kilometers — roughly three solar radii — above the Sun's surface. At closest solar approach, the probe would fire a rocket motor to increase its speed still further. This would give the craft an escape velocity high enough to take it across Neptune's orbit two years after solar passage. (By comparison, *Voyager 2* took a dozen years to reach Neptune.)

While its flight is not truly instantaneous, the *Interstellar Probe* does offer an exciting opportunity to send instruments across the heliosphere in a fraction of the solar cycle. If this probe were launched in the year 2000, it could reach 140 AU in half a solar cycle, or in about six years. By the time it goes that distance the probe will have presumably crossed the heliopause and probably the bow shock as well. The *Interstellar Probe* mission may thus represent our only opportunity to explore the local interstellar medium during the next twenty years — that is, within the working lifetimes of most astrophysicists today.

The *Interstellar Probe* is an ambitious project. If it flew according to schedule it would overtake the *Pioneers* and *Voyagers* like a Concorde passing a DC-3. It would also provide an essentially simultaneous look at different parts of the heliosphere because its readings could be compared with those of the *Voyagers.* But if the *Interstellar Probe* is never built, *Voyager 1* will remain our best hope of placing instruments beyond the edge of the heliosphere.

Getting a look at the mysterious realm outside this boundary is vitally important because we know so little about it. Astronomers have learned that the average density of material in interstellar space near the Sun is only about four atoms per cubic centimeter, and we know that the galactic magnetic field has a local strength of about two millionths of a gauss. Also, astrophysicists expect to detect a change in the character of cosmic rays when *Voyager 1* crosses into interstellar space. Perhaps they will show, uncontaminated by solar effects, the true spectrum of energies that galactic cosmic rays have.

Scientists have studied the terrestrial magnetosphere in detail and other planetary magnetospheres have been investigated well enough to provide overviews. The exploration of the heliosphere by means of the *Voyagers* is a good beginning, but we need to probe still deeper to find the edge. We have seen that magnetosphere-like systems are common not only in our solar system but, in all probability, throughout the universe. Astronomers have detected similar structures around rotating pulsars and even around radio-emitting galaxies such as NGC 1265, whose dimensions dwarf the Milky Way.

Solar system space research is now striving to understand nature's processes on a heliospheric scale. It is also seeking to provide a link between local phenomena belonging to our star and those occurring in space around us. The result of this will help us understand better our home in the universe. ☐

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Perfect for Meade LX6, LX5, and LX3; and Celestron Powerstar 8, and SPC-8 (with adapter). Also suitable for all drive correctors and motor drives. Battery is encased in high-impact polystyrene. Built-in handle. Wt. 5 lbs.

#2352 **$69 ea.** (4.56)

12 Amp Hour Porta Pac

Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper. Battery is encased in high-impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs.

#2354 **$99 ea.** (6.23)

Orion® Color Filters for Eyepieces

Solar system observations are dramatically improved by Orion colored filters. For visual use, thread one into the barrel of any standard eyepiece. For planetary and lunar photography, Schmidt-Cassegrain owners can attach the filter to the eyepiece inside the tele-extender. Can also be threaded directly into a universal camera adapter.

Basic Set of 4 Filters .965"
Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5510 Was $36.95 **Now $29.95** (1.89)

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Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5514 Was $44.95 **Now $39.95** (2.19)

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Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.

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Orion® Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

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Astronomer's Choice

Orion® SkyGlow™ Enhanced Broadband Light Pollution Filters

The Finest Photo-Visual Light Pollution Filters You Can Buy!

Hundreds of Amateur Astronomers have seen a dramatic improvement in light pollution reduction technology with the Orion SkyGlow Filter. The Enhanced SkyGlow Filter allows maximum transmission of the important wavelengths of Hydrogen Alpha, Hydrogen Beta, and Doubly Ionized Oxygen- the light "bands" most commonly emitted by nebulas. It provides better blocking of mercury vapor light and higher transmission than many competing models. With 90-95% efficiency, it noticeably improves contrast, especially when observing faint emission nebulas.

1.25" Broadband Filter- fits 1.25" eyepieces
#5660 **$66.50** (1.89)

Schmidt-Cassegrain Broadband Filter- fits rear cell of Meade & Celestron SC scopes
#5658 **$99** (2.19)

52mm Broadband Filter- fits all camera T-rings
#5668 **$66.50** (1.89)

Orion® Ultrablock™ SkyGlow™ Light Pollution Filters

The World's Finest Filters for Severe Light Pollution!

Orion UltraBlock SkyGlow filters can give you darker skies than you ever imagined. Observation of emission and planetary nebulas is even possible from areas where they are invisible without a filter.

UltraBlock SkyGlow filters block ALL forms of light pollution, including both narrow-band mercury and sodium vapor lighting and broadband light pollution sources. UltraBlock SkyGlow filters reject pollution from incandescent and fluorescent lighting, the type wide-band filters can't stop.

Extremely high (99.9%) blocking of critical mercury and sodium emission pollution bands and very high transmission of the critical Hydrogen Beta and Ionized Oxygen wavelengths result in the highest contrast gain of any competing light pollution filter.

1.25" Ultrablock Filter- fits 1.25" eyepieces
#5654 **$77.50** (1.89)

Schmidt-Cassegrain Ultrablock Filter- fits rear cell of Meade & Celestron SC scopes
#5656 **$119** (2.19)

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Get four times brighter image and twice the field of view. For Meade, Celestron 8", 10" Schmidt-Cassegrains.

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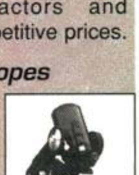

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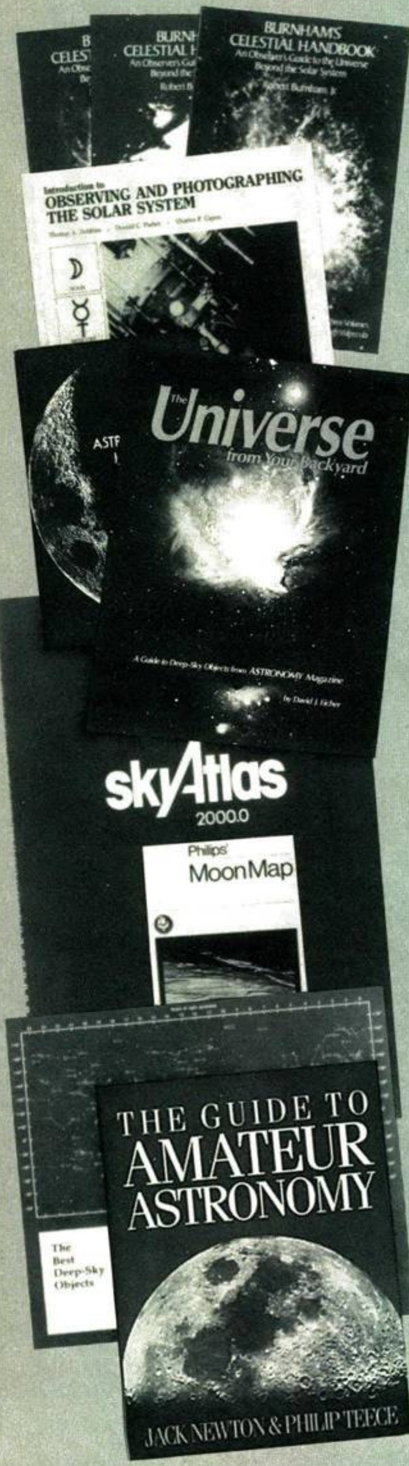
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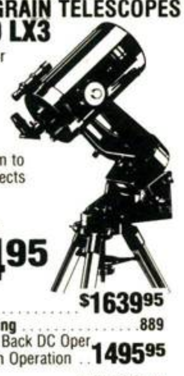

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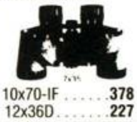

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The all-sky map shows how the sky looks at:
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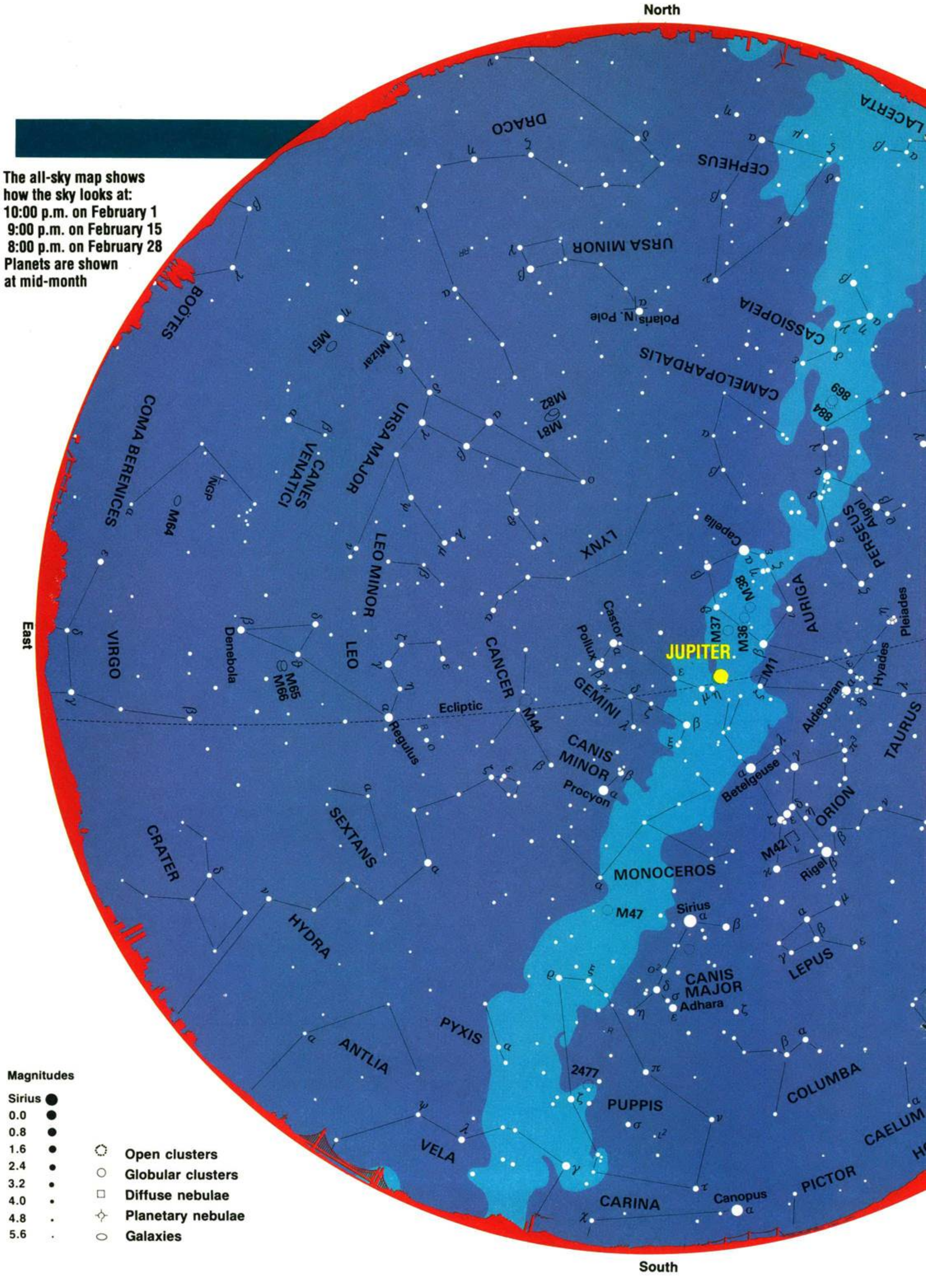
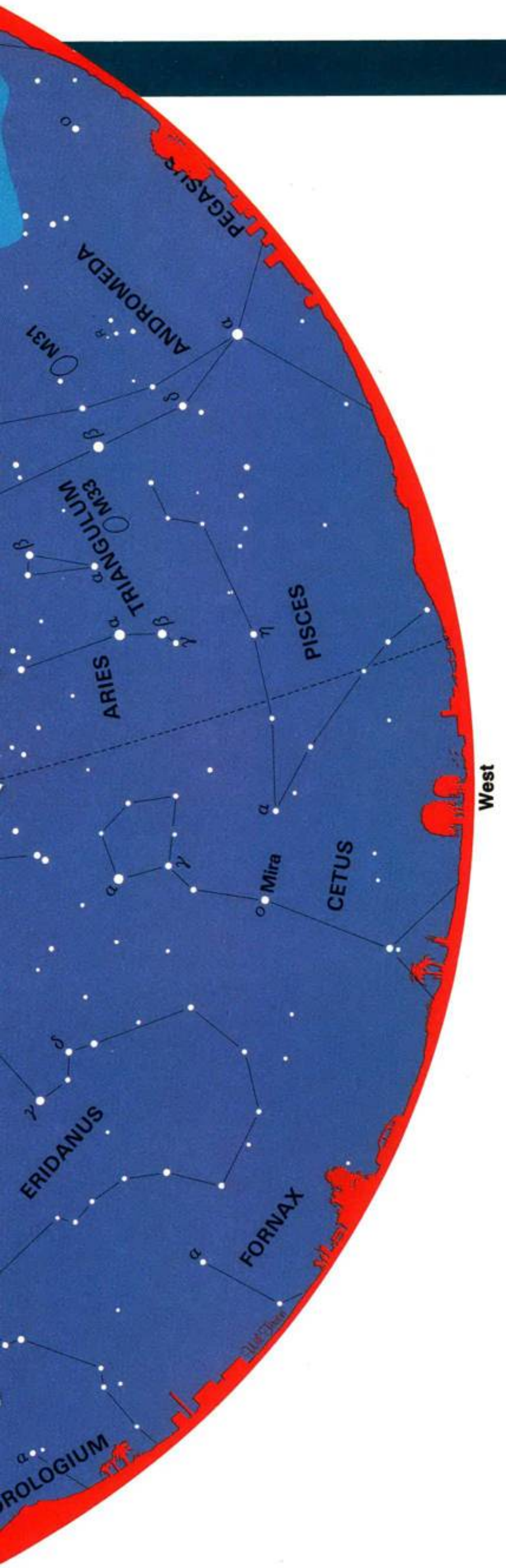
9:00 p.m. on February 15
8:00 p.m. on February 28
Planets are shown at mid-month


North
South
East
DRACO
CEPHEUS
LACERTA
URSA MINOR
Polaris N. Pole
CASSIOPEIA
CAMELOPARDALIS
BOÖTES
M51
Mizar
URSA MAJOR
CANES VENATICI
M82
M81
869
884
COMA BERENICES
NGP
M64
PERSEUS
Algol
LYNX
Capella
LEO MINOR
AURIGA
M38
M37
M36
Castor
Pollux
VIRGO
Denebola
M65
M66
LEO
CANCER
JUPITER
M1
Pleiades
Hyades
Aldebaran
TAURUS
GEMINI
Ecliptic
Regulus
M44
CANIS MINOR
Procyon
Betelgeuse
ORION
SEXTANS
CRATER
MONOCEROS
M42
Rigel
Sirius
M47
HYDRA
LEPUS
CANIS MAJOR
Adhara
PYXIS
ANTLIA
2477
PUPPIS
COLUMBA
VELA
CAELUM
PICTOR
CARINA
Canopus
Magnitudes
Sirius ●
0.0 ●
0.8 ●
1.6 ●
2.4 •
3.2 •
4.0 •
4.8 ·
5.6 ·
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies



February 1990

A GRAND ASSEMBLY OF PLANETS

Five of the six naked-eye planets appear near one another in the southeast in the predawn sky. Mercury, Venus, Mars, Saturn, and Uranus (along with Neptune) are particularly interesting on February 20, 21, and 22, when the slim crescent Moon passes by them.

JUPITER BRIGHT IN THE EVENING

Jupiter, the only major planet not visible in the morning sky, shines brilliantly from high in the evening sky. Observers with telescopes should monitor the planet's faded South Equatorial Belt.

LUNAR ECLIPSE ON FEBRUARY 9/10

A total eclipse of the Moon can be seen from most of Europe, Asia, Africa, and Australia on the night of February 9/10.

Dates and Times

1 The Moon is at perigee (230,019 miles from Earth), 9:43 p.m. EST

2 First Quarter Moon is at 1:32 p.m. EST

3 Mercury passes 0.2° north of Saturn, 10 a.m. EST

4 Mercury passes 7° south of Venus, 1 a.m. EST

5 The Moon passes 4° north of Jupiter, 11 p.m. EST

7 Venus passes 7° north of Saturn, midnight EST

8 Comet Tuttle-Giacobini-Kresak is at perihelion

9 Mars passes 0.2° south of Uranus, 9 a.m. EST
Full Moon is at 2:16 p.m. EST; total lunar eclipse

14 Venus passes 7° north of Saturn, noon EST

16 The Moon is at apogee (251,349 miles from Earth), 8:08 a.m. EST

17 Mars passes 1.5° south of Neptune, 1 a.m. EST
Last Quarter Moon is at 1:48 p.m. EST

18 The Moon passes 0.3° south of Antares, 11 a.m. EST

20 The Moon passes 3° south of Uranus, 7 p.m. EST

21 The Moon passes 4° south of Neptune, 5 a.m. EST
The Moon passes 2° south of Mars, 11 a.m. EST
The Moon passes 3° south of Saturn, 7 p.m. EST
The Moon passes 8° south of Venus, 11 p.m. EST

22 Venus is at greatest brilliancy (–4.6 magnitude)

23 The Moon passes 2° north of Mercury, 8 p.m. EST

24 Jupiter is stationary

25 New Moon is at 3:54 a.m. EST

28 The Moon is at perigee (227,257 miles from Earth), 3:06 a.m. EST
Mars passes 1.0° south of Saturn, noon EST

Eye on the Sky by Deborah Byrd

A GREAT MORNING LINEUP OF PLANETS

Three-quarters of all the planets lie close to each other in the southeast before dawn this month. Mars, Venus, and Saturn are easily seen with the naked eye. Mercury is bright enough to see when the month begins but it is low in the sky and soon travels back into the Sun's glare. The remaining two planets, Uranus and Neptune, are best seen with optical aid.

On February 1, Mars is highest in the predawn sky, but at magnitude 1.4 it is not conspicuous. Venus, which rises next, is more than two hundred times brighter than Mars at magnitude –4.4. You'll find Venus about 20° to the left of Mars and closer to the southeastern horizon.

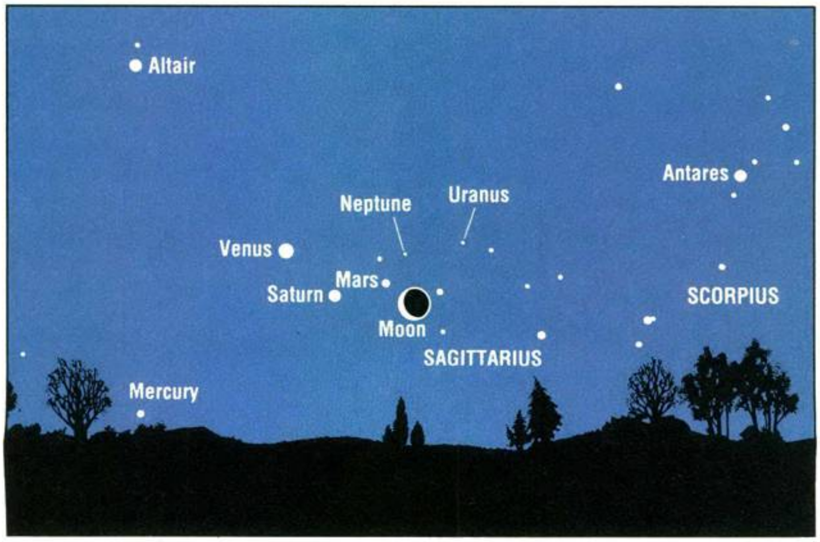
Meanwhile, Saturn and Mercury are even lower in the sky, more or less between Venus and Mars. Both are reasonably bright, with Mercury shining at magnitude –0.1 and Saturn at 0.6. They are far from conspicuous, however, because they appear so near the coming dawn. Binoculars will improve your view of the pair.

As you might expect from so grand an assembly of planets, February is a month of conjunctions. Mercury passes 0.2° north of Saturn on February 3 and 7° south of Venus the following day. Finally, on February 28 Mars passes 1° south of Saturn.

Throughout the month you can watch these planets hovering in the predawn sky, shifting their relative positions each day. Mars, Venus, and Saturn are particularly fine around the middle of the month when they form a triangle in the southeast. Look for them also on the mornings of February 20, 21, and 22, when the waning crescent Moon passes them. These celestial scenes are made even more special because Venus reaches greatest brilliancy, when it shines at magnitude –4.6, on February 22.

The Moon's passage through this area around February 21 should provide a spectacular view. The Moon first sweeps past Uranus, then Neptune, Mars, Saturn, and finally Venus within a period of only 28 hours. Two days later it passes Mercury, and although you can probably glimpse the Moon that morning, the planet will be difficult to see in the bright twilight.

SIX PLANETS GATHER in the southeast shortly before dawn in February where they are joined by a slender crescent Moon on the 21st (below). Dewey Vanderhoff captured seven planets in one shot in January 1984 (above).



JUPITER STILL BRIGHT

The evening sky in winter is graced with many bright stars, but one object up there this winter outshines them all. It's the largest planet in our solar system, Jupiter, which is still very bright at magnitude –2.5 and very well placed for evening viewing.

Jupiter appears well up in the east by nightfall and sets in the wee hours before dawn. The planet remains in Gemini among some of the sky's brightest stars — heroes of the winter night — which happen to lie in a circular pattern in our sky. These bright stars are sometimes called the Winter Circle, and Jupiter lies smack in the middle of them.

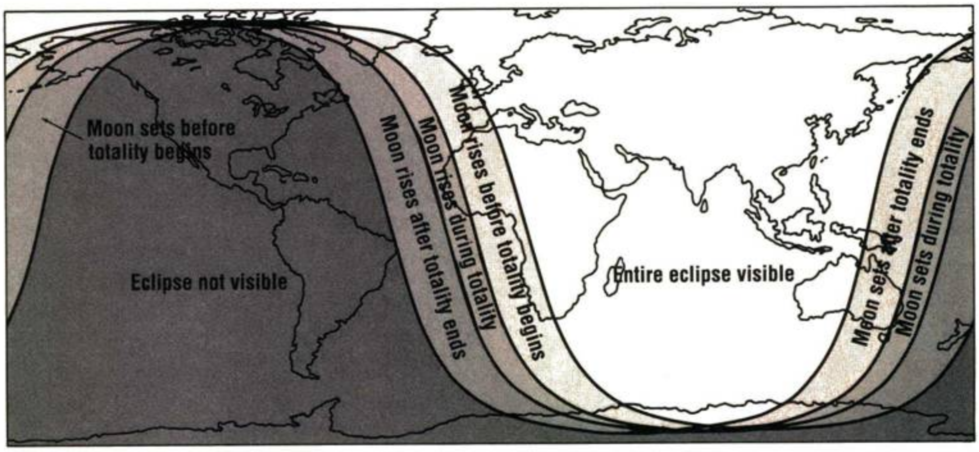
AN ECLIPSE OF THE MOON

There is a total eclipse of the Moon on February 9/10 when the Sun, Earth, and Moon line up and Earth's shadow falls on the Moon. Unfortunately for those of us in the contiguous United States, the eclipse occurs when the Moon is below the horizon.

Observers in Hawaii and

Alaska can see the early phases of the eclipse on the morning of February 9. The eclipse begins when Earth's lighter, penumbral shadow falls on the Moon. A penumbral eclipse is extremely subtle, however, and the Moon is poorly positioned — low in the west shortly before sunup — as seen from Hawaii and eastern Alaska. From those locations the Moon sets before the dark umbral shadow begins inching across the Moon.

The beginning stage of the umbral eclipse and the first part of totality are visible from western Alaska, yet Earth spins on and the Moon sets before totality ends. The best place to see this lunar eclipse is from the opposite side of the globe on the night of February 9/10.


Moon sets before totality begins
Eclipse not visible
Moon rises after totality ends
Moon rises during totality
Moon rises before totality begins
Entire eclipse visible
Moon sets after totality ends
Moon sets during totality

A TOTAL LUNAR ECLIPSE can be seen from most of the Eastern Hemisphere and parts of Alaska on February 9/10.

FEBRUARY'S PLANETS

Jupiter dominates the February evening sky from its position high overhead. It is still in Gemini, where it shines at magnitude –2.5, a whole magnitude (or two-and-a-half times) brighter than the sky's brightest star, Sirius.

Mars leads the procession of morning planets that rises in the southeast before dawn. Like the five other planets in this part of the sky, Mars is in Sagittarius when the month begins. It remains in that constellation all month but will pass into Capricornus in early March.

The Red Planet brightens a bit in February, from magnitude 1.4 to 1.2. It's nothing to write home about yet, but it is destined to grow much brighter as its November opposition approaches.

Mars, Venus, and Saturn form a large triangle at mid-month. By late February Saturn has edged closer to Mars and the two have a conjunction on February 28. Mars then lies 1° south of Saturn. The three planets make a second triangle in March, although by then their relative positions have changed.

Venus is by far the brightest of the planets in the southeast before dawn. That should come as no surprise because it's normally the brightest planet. It reaches greatest brilliancy on February 22. By then Venus shines at magnitude –4.6 and it stays that bright through the first week of March.

Mercury begins the month at greatest western elongation when it lies 25° west of the Sun in the predawn sky. This is a grand apparition of Mercury for those in Earth's Southern Hemisphere; unfortunately, the view from up north is not nearly as good.

The planet is in the predawn sky throughout February, but it's easiest to see at the beginning of the month. Mercury is then slightly more noticeable because of its nearness to Saturn. The two pass only 0.2° from each other on February 3.

Mercury isn't easy to see this month primarily because the ecliptic — the apparent path of the Sun, Moon, and planets across the sky — makes a shallow angle with the eastern horizon on February mornings. In the Southern Hemisphere this situation is reversed: the ecliptic makes a steep angle with the horizon and Mercury rides high in the predawn sky.

On the positive side, Mercury brightens from magnitude –0.1 to –0.4 during the month. It does so because, while its distance from us is increasing and its angular size is thus decreasing, more of its illuminated hemisphere faces us. In other words, as it moves toward the far side of the solar system, Mercury waxes toward full.

But, alas, as Mercury brightens it also sinks closer to the horizon, which makes the planet more difficult to see. As Roseanne Rosannadanna of Saturday Night Live used to say, "It's always something."

Saturn spent most of January creeping back into our predawn sky after a brief sojourn behind the Sun. Look for it below Mercury as February begins. Neither planet is very high in the sky but you should see them if your sky is clear and your horizon unobstructed.

Saturn sweeps closely past Mercury on February 3 when it is slightly dimmer than the other planet at magnitude 0.6. It still shines at that magnitude when it appears near Mars at month's end.

Like the other planets, Saturn is in front of Sagittarius, but in Saturn's case it's no surprise. Because it takes thirty years to complete one orbit around the Sun, Saturn moves slowly relative to the stars. It hasn't crossed a constellation boundary since early 1988 and won't leave Sagittarius until 1991.

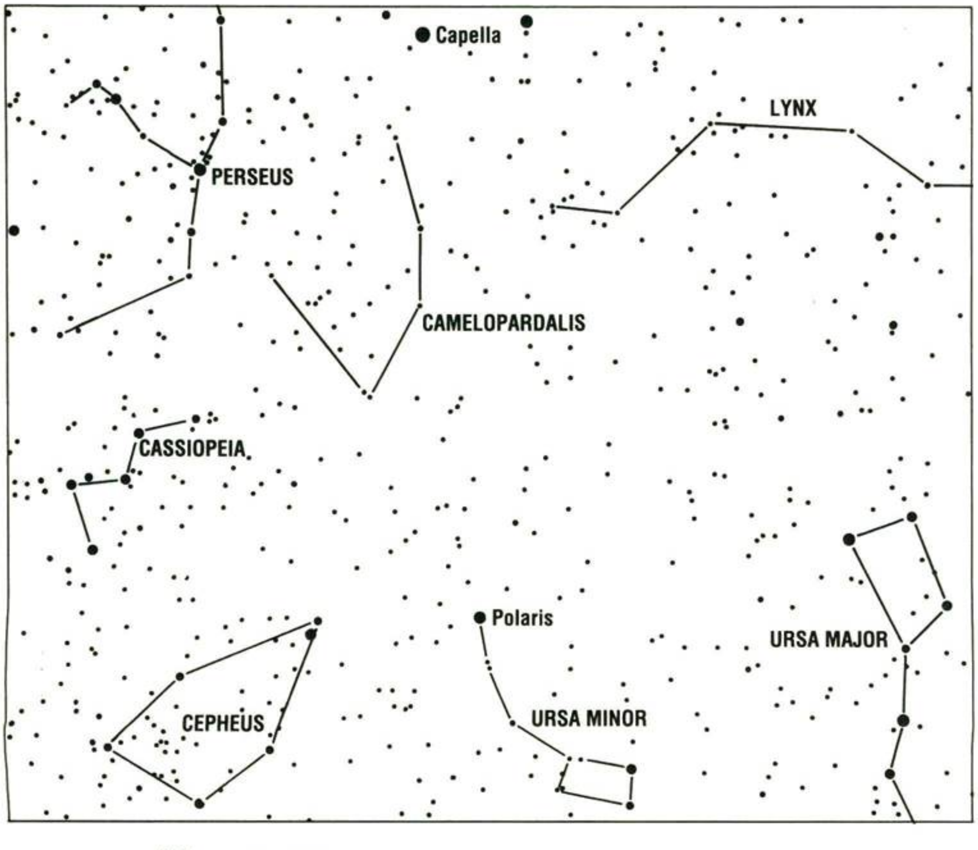
FEBRUARY'S STARRY SKY

The evening sky in winter is known for its dazzling array of bright stars. Yet if you look toward the north on a winter evening, you'll find what appears to be a rather empty expanse of sky. Even here, however, there are constellations. Every inch of the sky is divided into constellations, although some are much fainter than others.

Such is Camelopardalis, a long name for a faint, northern constellation that represents a giraffe. It lies in an area surrounded by Cassiopeia, Perseus, Auriga, Lynx, Ursa Major, Draco, and Ursa Minor. Its four brightest stars shine only dimly at 4th magnitude.

You need a very dark sky to trace the giraffe's winding pattern. After you do so, you may agree with Richard Hinckley Allen, author of the book *Star Names: Their Lore and Meaning*, who wrote that Camelopardalis is "long, faint and straggling like its namesake."

Like many other faint constellations, Camelopardalis wasn't named by the ancient stargazers. It is the largest of the so-called "modern" constellations, ranking 18th in size among all constellations.



CAMELOPARDALIS is a faint constellation that is high in the sky in the early evening hours of February. Look directly north, between the bright stars Capella and Polaris, to find Camelopardalis.

Astronomers aren't certain who invented this constellation, but it was included in a 1624 atlas called *Planisphaerium Stellatum*, compiled by Jakob Bartsch. To him this grouping represented the camel that brought Rebecca to Isaac in the biblical legend. It was a quaint story for an otherwise undistinguished constellation, but it didn't really fit since Camelopardalis means giraffe, not camel.

The word comes from a Latin word that originated in ancient Rome, where a giraffe was described as having the hump of a camel and the spots of a leopard. The combination of the two animals gives us the name "camelleopard," or Camelopardalis.

A camel may be more appropriate, however. Camels bring to mind deserts, and so does the place in the sky where this constellation resides. Interestingly, the Chinese saw seven asterisms within the boundaries of this faint region, including one called Yin Tih, or Unostentatious Virtue!

Through the Eyepiece by Rick Shaffer

A CORNUCOPIA OF CONJUNCTIONS

Six planets lie near each other in the February predawn sky. Although the complete gathering itself is visible only with the naked eye, telescope owners have several close conjunctions to look forward to this month.

The first occurs on the morning of February 3 when Mercury passes just 13' north of Saturn. Look for the two planets low in the southeast about 30 minutes before sunrise. Observers in Alaska and Hawaii get to see the planets closest to the time of conjunction, while observers in the rest of North America can see the pair a few hours before closest approach. Even for those on the East Coast, however, the planets lie within 0.3° of one another.

In the eyepiece Mercury appears as a tiny, slightly yellowish disk just 6.5" in diameter, while Saturn sports a pale yellow disk that measures 15.2" across and rings that span 34.6". Although Saturn is only 0.7 magnitudes fainter than Mercury overall, its average surface brightness is 3.7 magnitudes fainter than Mercury's. Thus, each square arcsecond of Mercury's disk appears 30 times brighter than each square arcsecond of Saturn's disk.

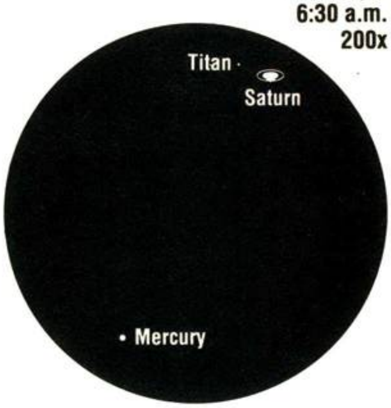
As you observe the two planets, remember that Mercury is a rocky planet that lies close to the Sun and Saturn is a remote gas giant. You can also use your mind's eye as you observe the differences between Mercury and Saturn's largest satellite, Titan. Titan is more than ten times as far away as Mercury and so it appears as little more than an 8th-magnitude dot through a telescope, even though its diameter is actually 170 miles greater than Mercury's. The top diagram at right will help you identify Titan relative to Mercury and Saturn in your field of view.

The next close conjunction occurs on the morning of February 9 when 1.4-magnitude Mars passes 13' south of 5.8-magnitude Uranus. Because both planets orbit the Sun at a fair distance, they move quite slowly across the sky, so observers throughout North America can see the pair close to each other. The planets differ little in apparent diameter — Mars' disk is only 1" larger than Uranus' 3.5"-diameter disk — but the orange-red color of Mars stands in stark contrast to Uranus' blue-green orb.

Mars is also involved in the final two close conjunctions of February. On the 17th, Mars passes 1.5° south of Neptune. The two planets lie a bit over 1° east of a pair of 5th-magnitude stars, Nu^1 (ν^1) and Nu^2 (ν^2) Sagittarii. The Red Planet appears very slightly larger and brighter than it did at the Uranus conjunction, and it tends to overwhelm the 8.0-magnitude, 2.2"-diameter, blue-gray disk of Neptune.

Last but not least, Mars passes 1.0° south of Saturn on February 28. This is probably the most interesting conjunction of the four, because telescopically these two planets have more to offer than Mercury, Uranus, and Neptune. Mars is again slightly larger and brighter than at its conjunction with Neptune, while Saturn is the same brightness but a bit larger than at its conjunction with Mercury.

When you view any of these events, start out with a low-power eyepiece. This gives you the best view of the planets' contrasting colors. After you've observed the color differences, raise the magnification and look for details on the planets' disks and in the rings of Saturn. However, don't expect to see any detail on either Uranus or Neptune.


February 3
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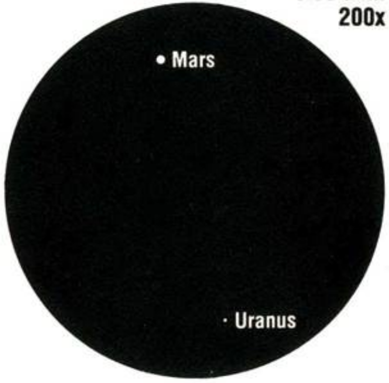
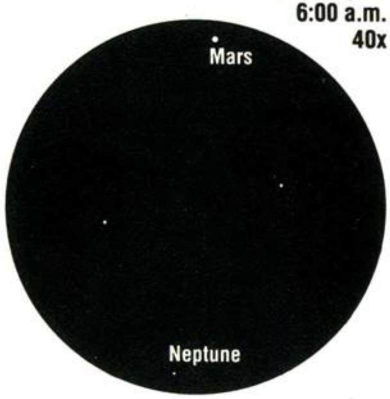
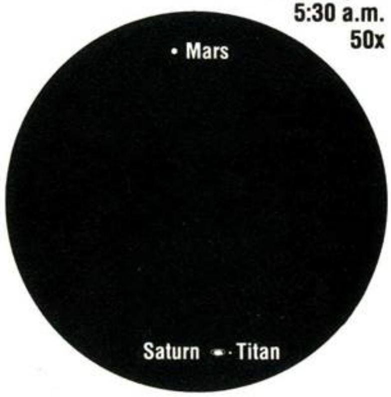
200x


February 9
6:00 a.m.
200x

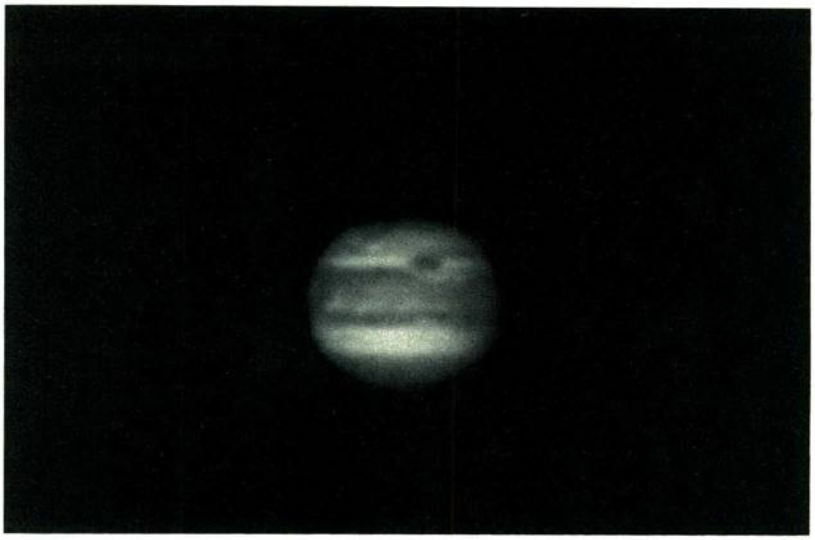

February 17
6:00 a.m.
40x


February 28
5:30 a.m.
50x

FOUR EXCITING planetary conjunctions occur during February. The diagrams show what each conjunction will look like as seen through an 8-inch f/10 SCT with south at top.

JUPITER HOLDS CENTER STAGE

Although most of the planetary action is in the morning sky this month, there is one grand exception: Jupiter. Northern Hemisphere observers are now enjoying the second half of an extraordinary apparition of Jupiter brought to us by the planet's northerly declination, which is greater than 23° all month. For the typical observer in mid-northern latitudes, this means Jupiter reaches an elevation of over 70° when it crosses the local meridian at about 8:30 p.m. local time. Jupiter is also



THE GREAT RED SPOT darkened slightly in late 1989 but it has a ways to go before it appears as dark as it did in this 1978 photo by Tom Rotkiewicz. The Red Spot can be seen for two to three hours before and after the times listed below.

TRANSIT TIMES OF JUPITER'S GREAT RED SPOT

Date	Time
February 2	5:07 a.m.
February 3	12:58 a.m.
February 3	8:50 p.m.
February 5	2:37 a.m.
February 5	10:28 p.m.
February 7	4:15 a.m.
February 8	12:07 a.m.
February 10	1:45 a.m.
February 10	9:37 p.m.
February 12	3:24 a.m.
February 12	11:15 p.m.
February 15	12:54 a.m.
February 15	8:45 p.m.
February 17	2:32 a.m.
February 17	10:23 p.m.
February 19	4:11 a.m.
February 20	12:02 a.m.
February 22	1:40 a.m.
February 22	9:32 p.m.
February 24	3:19 a.m.
February 24	11:10 p.m.
February 27	12:49 a.m.
March 1	2:27 a.m.

Transits visible throughout the United States and Canada in February. Times are in EST; subtract 1 hour to convert to CST, 2 hours for MST, and 3 hours for PST.

high in the sky at sunset.

Because seeing is usually best when an object is high in the sky, you should begin observing Jupiter just after sunset and follow it as it approaches culmination. Be sure to examine the planet's South Equatorial Belt. I can't tell you what the Belt may look like, because, as I write this in mid-October, it has faded to near invisibility. By February, however, the South Equatorial Belt may either be making a comeback or it may still be very faint.

Speaking of comebacks, it now appears from many observer's reports that the Great Red Spot is once again reddening. I know that there have been false alarms before, but this appears to be the real thing. The dynamic changes in both the South Equatorial Belt and the Red Spot are well worth capturing, either on film or by sketching the planet. If you have the chance and the inclination, try to photograph or draw Jupiter's disk to record these rapidly changing phenomena.

As you view the South Equatorial Belt/Great Red Spot complex, remember that what you're seeing is not a solid surface but the tops of Jupiter's clouds. The disappearance of the Belt and the reddening of the Red Spot are probably better described as changes in the chemical composition of those features and not as their physical disappearance or reappearance. Thus, the Great Red Spot hasn't been absent during the last few years, it's just been very hard to see because its color has been so similar to that of the South Equatorial Belt. (This discussion raises one more question: Is the Red Spot really reddening, or does it merely appear redder in comparison to the now-faded South Equatorial Belt?)

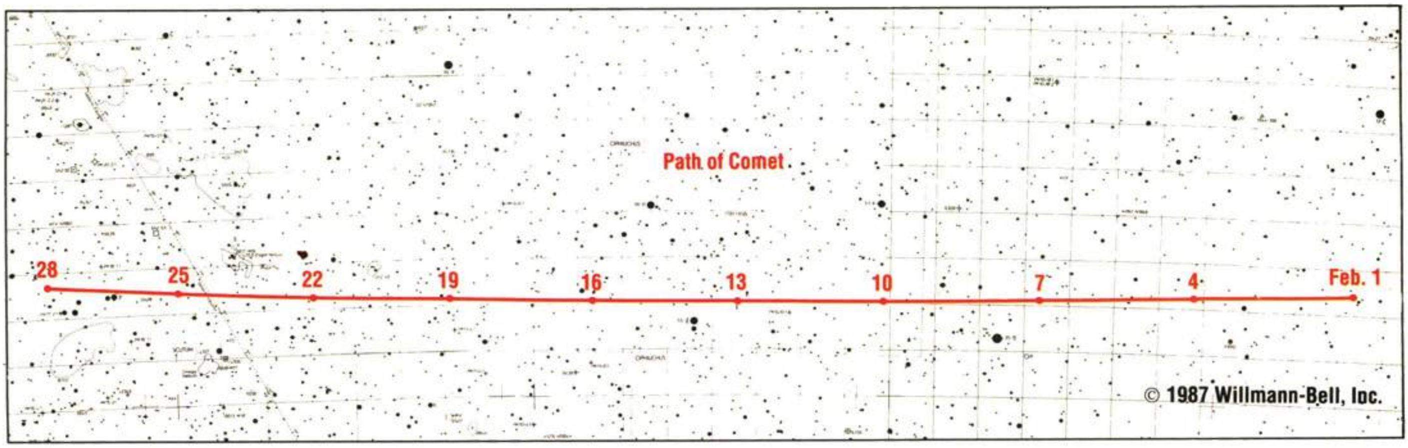
Jupiter doesn't make any close approaches to its planetary brethren this month, but it does pass close to a bright star. During the last week of February Jupiter approaches to within 14' of the 4.2-magnitude star 1 Geminorum. The star lies just southwest of the giant planet. Expect 1 Geminorum to appear slightly brighter than the Galilean satellites and somewhat farther away from Jupiter.

The main disadvantage in Jupiter being high in the sky at this time of year is that the atmosphere during the winter months is usually turbulent. However, for a brief period just after sunset it can be quite steady. As the atmosphere makes its transition from day to night, the air can have essentially the same temperature regardless of altitude and thus be remarkably free of turbulence. Although the atmosphere doesn't always behave this way, it does so often enough that you should be ready to take advantage of the good seeing that results.

Jupiter's excellent location in the early evening sky is not only convenient for your observing but for others as well. Have your kids or your neighbor's kids ever seen Jupiter and its moons in a telescope? What about the retired couple down the block? They might get a kick out of seeing Jupiter for a few minutes after dinner. I've shown the sky to kids as young as two years old and senior citizens as old as ninety, and it's always been extremely rewarding for both me and them. Why not give it a try on a clear night this month?

VENUS AT ITS BRIGHTEST

Venus reemerges from the twilight glow this month, shining brilliantly in the southeast before dawn. This morning apparition closely



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COMET TUTTLE-GIACOBINI-KRESAK should shine at 12th magnitude in February but it could flare by ten magnitudes, as it has in the past. The comet's positions are shown for the beginning of morning twilight when it appears about 30° above the southeast horizon.

resembles Venus' evening apparition of late 1989, because the ecliptic makes a shallow angle relative to the horizon and Venus remains fairly low in the sky.

Despite its relatively low altitude, Venus is an interesting telescopic sight. On February 1 the brightest planet shines at magnitude –4.4 and its 7-percent-illuminated disk measures 57" across. By the end of the month the planet shrinks to only 37" in apparent diameter, but the illuminated portion of its disk swells to 30 percent. Venus reaches its greatest brightness for this apparition during the last week of February when it shines at magnitude –4.6.

THE MOON IN ECLIPSE

Most of the Eastern Hemisphere can see a total lunar eclipse on the night of February 9/10. In the Western Hemisphere, about the only people lucky enough to see the Moon pass through Earth's shadow are those in Alaska. For them the eclipse occurs in the predawn hours of February 9. In the rest of North and South America the Moon remains below the horizon throughout the eclipse. Use the map on page 55 to find out if you'll be able to see the eclipse.

TELESCOPIC PLANETS

Before gliding by Saturn on February 3, Mercury reaches greatest western elongation on January 31/February 1. On the 1st, Mercury's 62-percent-illuminated, 6.7"-diameter disk shines at –0.1 magnitude. Mercury needs all that magnitude to attract your attention, however, because it is only about 10° above the horizon 30 minutes before sunrise. Mercury remains visible at dawn throughout the month, but it grows smaller in the eyepiece and sinks closer to the horizon, which makes it more difficult to see. At the end of the month it lies well below the other five planets in the southeast, where it shines at magnitude –0.4 and displays a 5.1"-diameter, 91-percent-lit disk.

COMETS FOR THE TELESCOPE

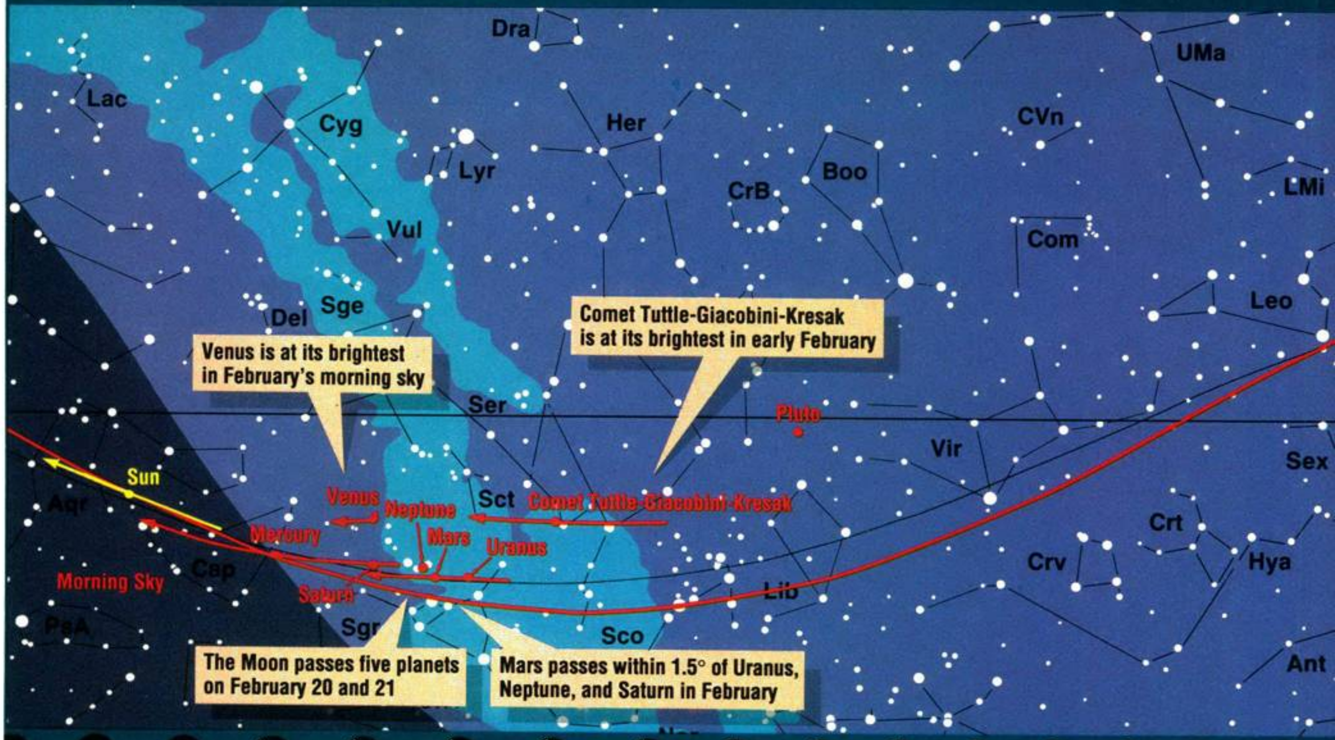
Comet Tuttle-Giacobini-Kresak reaches perihelion on February 7/8 and is well placed for observing in late January and early February and again in late February when the Moon is out of the sky. This periodic comet is predicted to shine between 11th and 12th magnitude all month, but it has been known to flare as much as ten magnitudes in its illustrious past. Try to observe it every clear night, because no one knows when the comet might flare again.

The comet begins February in western Ophiuchus then moves into Serpens Cauda and ends the month in Scutum. You can use the finder chart on this page to locate Comet Tuttle-Giacobini-Kresak. Or you can plot the comet's positions given in the table of coordinates on a good star atlas such as *Sky Atlas 2000.0* or *Uranometria 2000.0.* ☐

COORDINATES FOR COMET TUTTLE-GIACOBINI-KRESAK

Date	R.A. (2000)	Dec.
Feb. 1	16h38.7m	–14°38'
Feb. 4	16h52.8m	–14°49'
Feb. 7	17h06.7m	–14°56'
Feb. 10	17h20.4m	–15°00'
Feb. 13	17h33.7m	–15°01'
Feb. 16	17h46.7m	–14°58'
Feb. 19	17h59.4m	–14°53'
Feb. 22	18h11.8m	–14°45'
Feb. 25	18h23.8m	–14°35'
Feb. 28	18h35.4m	–14°23'

The Solar System February 1990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CrB
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Venus is at its brightest in February's morning sky
Comet Tuttle-Giacobini-Kresak is at its brightest in early February
Ser
Pluto
Vir
Sex
Sun
Aqr
Venus
Neptune
Sct
Comet Tuttle-Giacobini-Kresak
Crt
Mercury
Mars
Uranus
Crv
Hya
Morning Sky
Cap
Saturn
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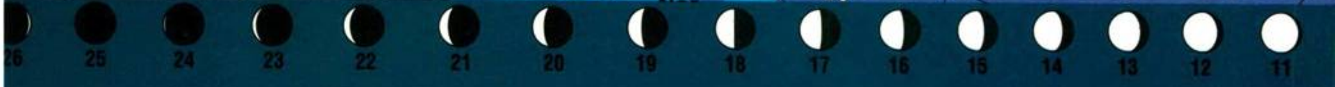
Ant
The Moon passes five planets on February 20 and 21
Mars passes within 1.5° of Uranus, Neptune, and Saturn in February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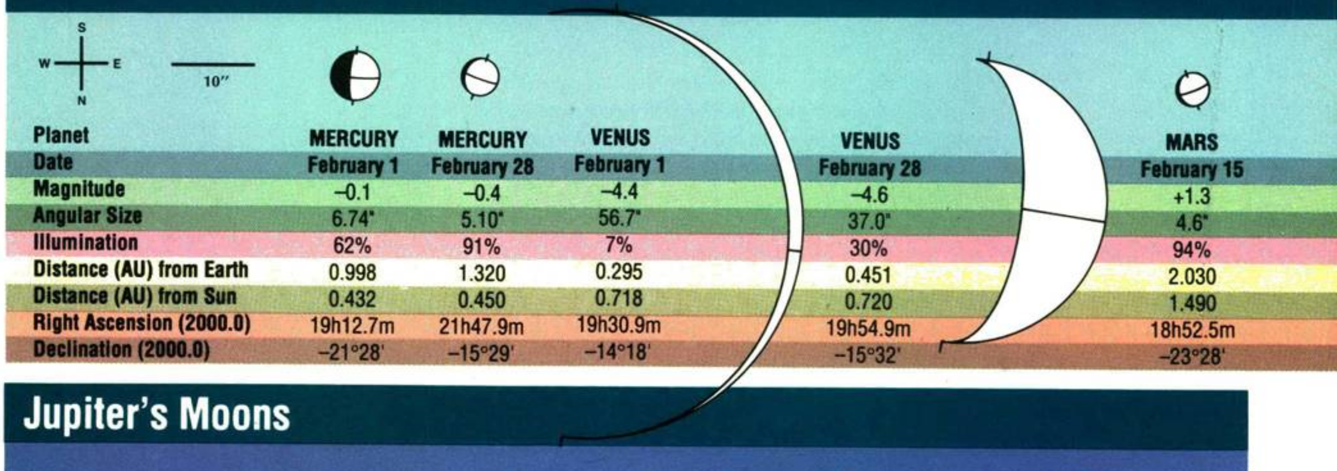
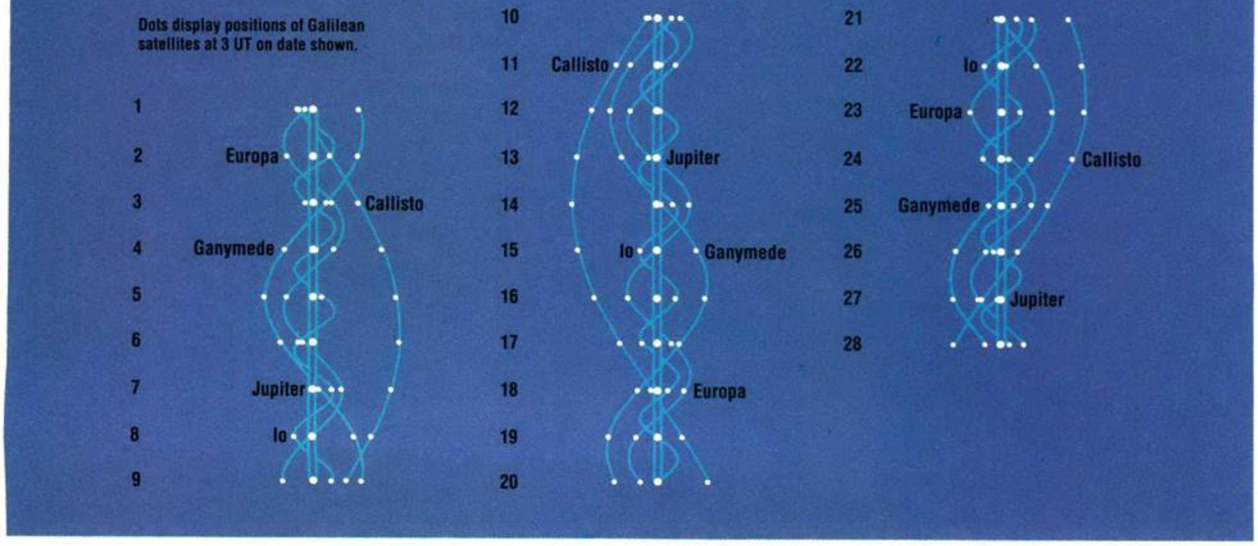
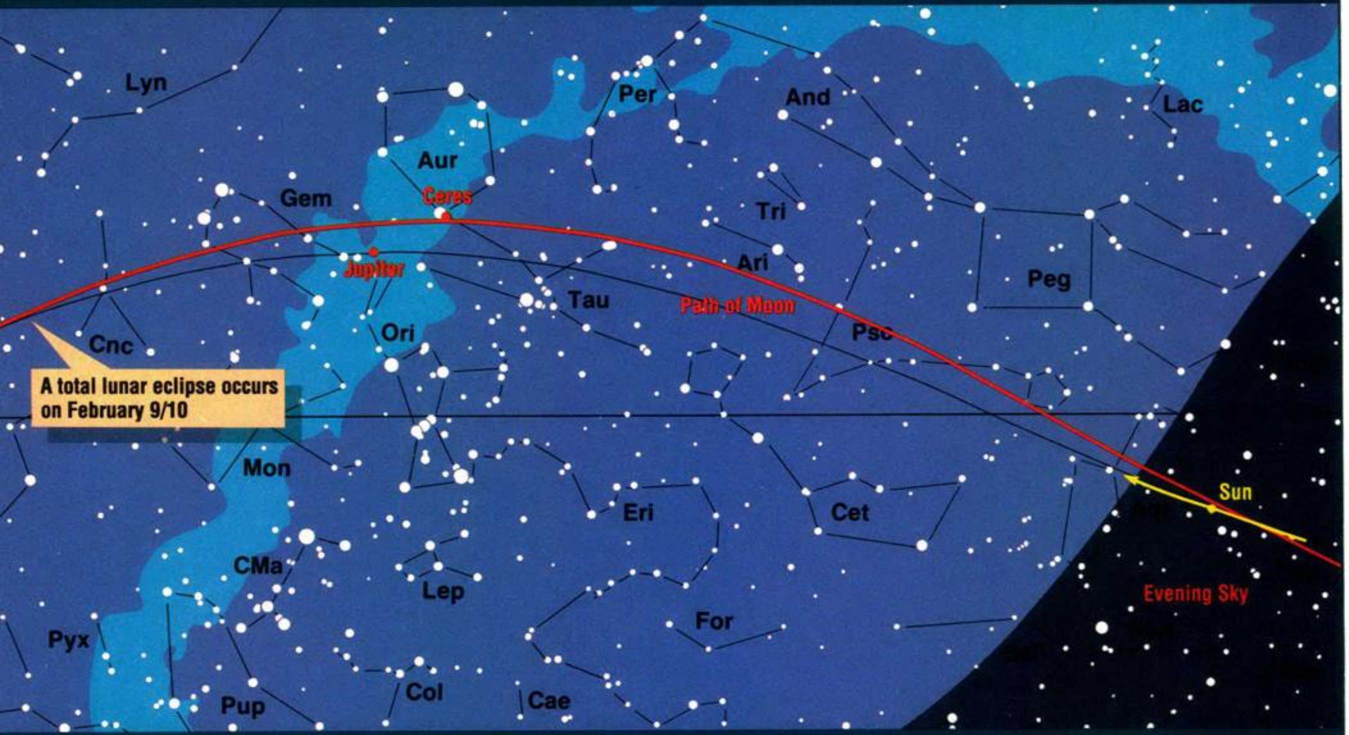


Planet	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	February 1	February 28	February 1	February 28	February 15
Magnitude	–0.1	–0.4	–4.4	–4.6	+1.3
Angular Size	6.74"	5.10"	56.7"	37.0"	4.6"
Illumination	62%	91%	7%	30%	94%
Distance (AU) from Earth	0.998	1.320	0.295	0.451	2.030
Distance (AU) from Sun	0.432	0.450	0.718	0.720	1.490
Right Ascension (2000.0)	19h12.7m	21h47.9m	19h30.9m	19h54.9m	18h52.5m
Declination (2000.0)	–21°28'	–15°29'	–14°18'	–15°32'	–23°28'

Jupiter's Moons



Dots display positions of Galilean satellites at 3 UT on date shown.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Evening Sky
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Pyx
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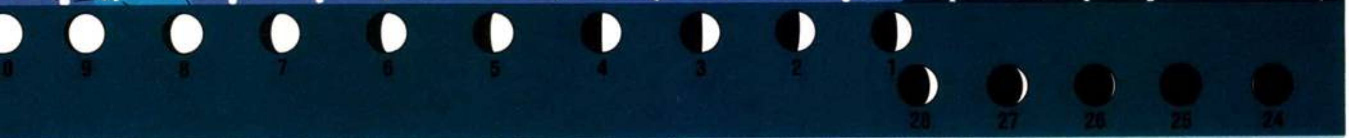
Cae
Pup

A total lunar eclipse occurs on February 9/10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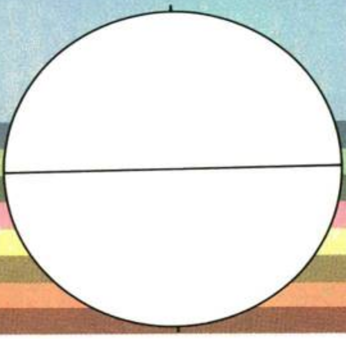
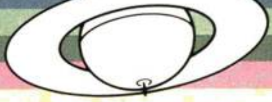
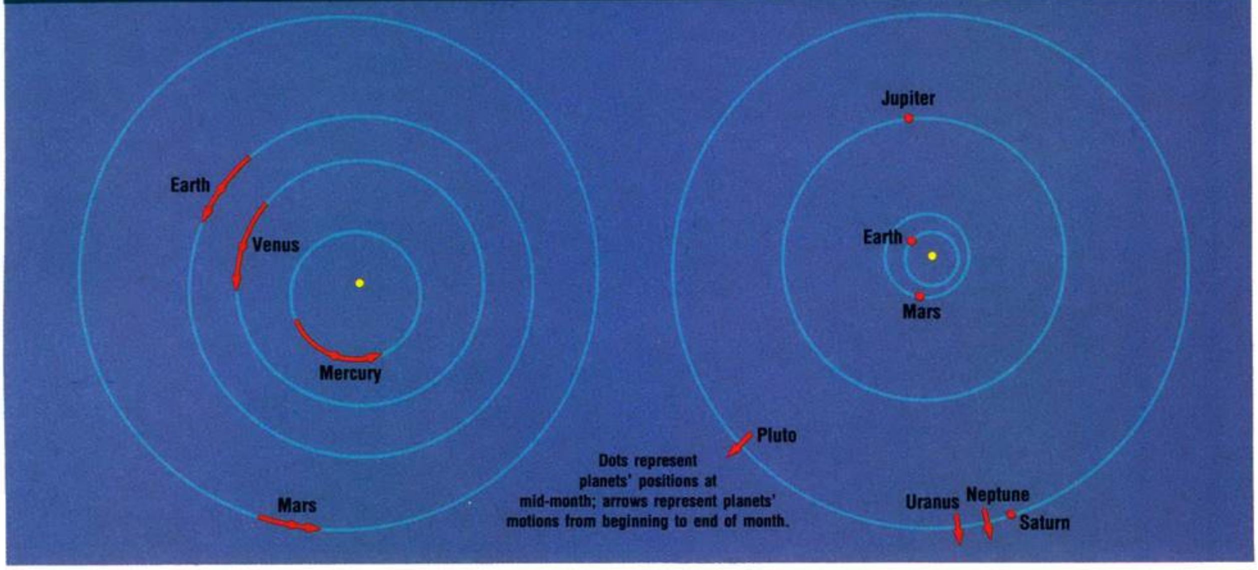




	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
	February 15	February 15	February 15	February 15	February 15
	–2.5	+0.6	+5.8	+8.0	+13.7
	43.4"	15.3"	3.5"	2.2"	0.1"
	99%	100%	100%	100%	100%
	4.538	10.814	20.037	30.931	29.504
	5.167	10.024	19.388	30.209	29.657
	6h04.8m	19h30.1m	18h36.4m	18h59.3m	15h19.1m
	23°26'	–21°35'	–23°27'	–21°53'	–2°08'

The Planets in Their Orbits


Earth
Venus
Mercury
Mars
Jupiter
Earth
Mars
Pluto
Uranus
Neptune
Saturn

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

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ASTROPHOTO OF THE MONTH

The "Dumbbell Nebula," M-27 in Vulpecula. The "ears" of the Dumbbell are seen best visually with a Lumicon UHC Filter. Photo by David Healy using a Lumicon Giant EASY-GUIDER and Lumicon hypersensitized 2415 film, 30 min., C-14 at f/6.

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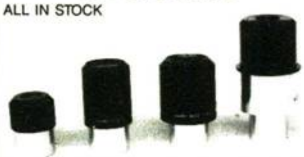

Genesis 4" f/5.5 Fluorite Apochromat	$1350
Renaissance 4" f/5.5. Telescope	$1450
7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	**$89**
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32mm Plossl, widest true field in 1¼"	**$109**
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19mm Wide-Field, 1¼" eyepiece, 85°	**$145**
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32mm Wide-Field, 2" eyepiece, 65°	**$239**
40mm Wide-Field, "awesome," 65°	**$299**
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7mm Nagler, 1¼" eyepiece, 82° field	**$189**
9mm Nagler, 82° field, "the best"	**$219**
11mm Nagler, 82° field, 1¼" or 2"	**$235**
13mm Nagler, 82° field, 1¼" or 2"	**$249**
12mm Nagler, Type II, 82°, 1¼"/2"	**$249**
16mm Nagler, Type II, 82°, 1¼"/2"	**$289**
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The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 90-97%.

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Zepernick, Cresskill, NJ

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DEEP-SKY ASTROPHOTOGRAPHY

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U.S. Patent 4,473,636

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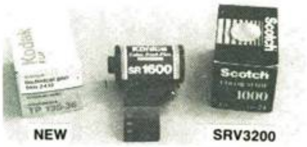

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Film Type, 35mm	**Exposures**	**Price**
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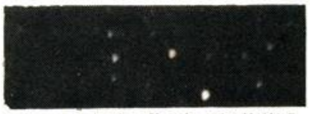

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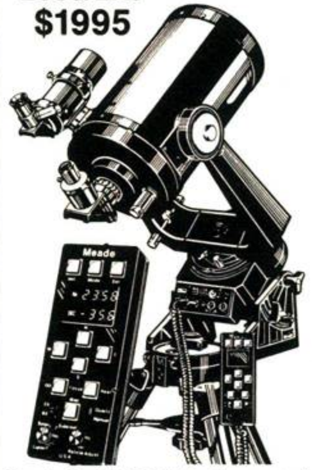

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1.8x Multiplier Lens

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ASTRONOMY Tests the
Epoch Instruments 'Shake-Enders'

ASTRONOMY reports on a new product that can substantially improve stability in a telescope mounting.

by Robert Burnham

When ASTRONOMY reviewed the Celestron Ultima 8 (May 1989), a dozen small refractors (October 1989), and Meade's 2120/LX6 (December 1989), we noted that most of the telescopes' mountings were shakier than we liked. This, however, is not a problem that belongs to these manufacturers alone.

Our experience with many different telescopes — ones we have owned over the years and those we have used at star parties and amateur meetings — indicates that a great many commercial and homebuilt telescopes, *probably even the majority of them,* have portable mountings with less-than-optimal stability. We also hear this complaint so frequently from readers that it's clear the problem of telescope shakiness is a general one that few backyard astronomers can hope to escape.

Over the years observers have concocted many ingenious remedies for lessening the problems of a shaky mounting. These include hanging weights from the tripod, filling a hollow pier with dry sand, and installing guy-wires and turnbuckles between the equatorial head and the ends of the legs. However, short of buying a new, heavy-duty mounting at a cost that may exceed that of the original telescope, telescope owners who don't want to perform surgery on their mounting will find very few commercial products available to reduce vibration.

We decided to test the Shake-Ender footpads manufactured by Epoch Instruments because, although they are not cheap, it appeared they might be helpful in reducing the vibration of a telescope mounting. We found that while a set of Shake-Enders will never make a fundamentally wiggly mounting rock-solid, they do make observing more enjoyable because they help vibrations dampen out in a significantly shorter time.

A Shake-Ender footpad is made of two nested aluminum castings separated by a 1/4-inch-thick layer of soft silicone rubber. The outer casting is 3 1/4 inches in diameter and it stands 1 1/4 inches high. The top surface of the inner casting has a 1/4-inch-deep bowl-shaped depression that steps down to a bottom 5/8 inch in diameter. The underside of the outer casting has three "buttons," each 3/16 inch high, that give the Shake-Ender a firm, three-point contact on a hard surface. (The manufacturer recommends when you install a Shake-Ender under the leg of a tripod that you point one of the buttons outward.)

SHAKE-ENDERS have buttons underneath to assure 3-point surface contact.

Shake-Enders are sold in sets of three at a cost of $59.95, plus an additional shipping and handling charge of $3. A similar device, made under license from Epoch Instruments, is being marketed by Celestron. This version differs in that the aluminum has been replaced with nylon; the list price is $72 for a set of three.

The principle behind the Shake-Ender design is simple. The device puts a layer of soft rubber between the part of the footpad that is in contact with the ground and the part that directly supports the tripod leg. The rubber has the property of absorbing a wide spectrum of vibration frequencies, so the mechanical energy of vibration is conducted down the tripod from the telescope to the rubber where it is quickly dissipated. The result is that vibrations damp out fast.

We tested our set of Shake-Enders with two Schmidt-Cassegrain telescopes: Celestron's 8-inch Ultima 8 and Meade's 10-inch 2120/LX6. We erected the 2120 (on a SuperWedge) and the Ultima outdoors on surfaces of asphalt, grass, and packed dirt. We aimed the telescopes upward at a 45° angle to simulate a typical observing configuration. Inserting eyepieces that gave 160x (the 2120) and 169x (the Ultima), we observed a tiny detail on the cornice of our office building while we tapped lightly on the tube. There was a slight wind blowing, but it was not strong enough to jiggle the telescopes. The temperature was in the middle 40's and the silicone rubber remained soft. (Epoch says the rubber should remain usable in temperatures ranging from –20° F to +180° F.)

The results are in the table at right. The numbers show the time in seconds that it took for all visible motion to die away after the tube was tapped. To minimize the inevitable variations between taps, each number is the average of at least three taps. The **boldface** numbers show the results obtained with the Shake-Enders under the tripod feet; the figures in ordinary type give the results with the tripod as supplied by the manufacturer.

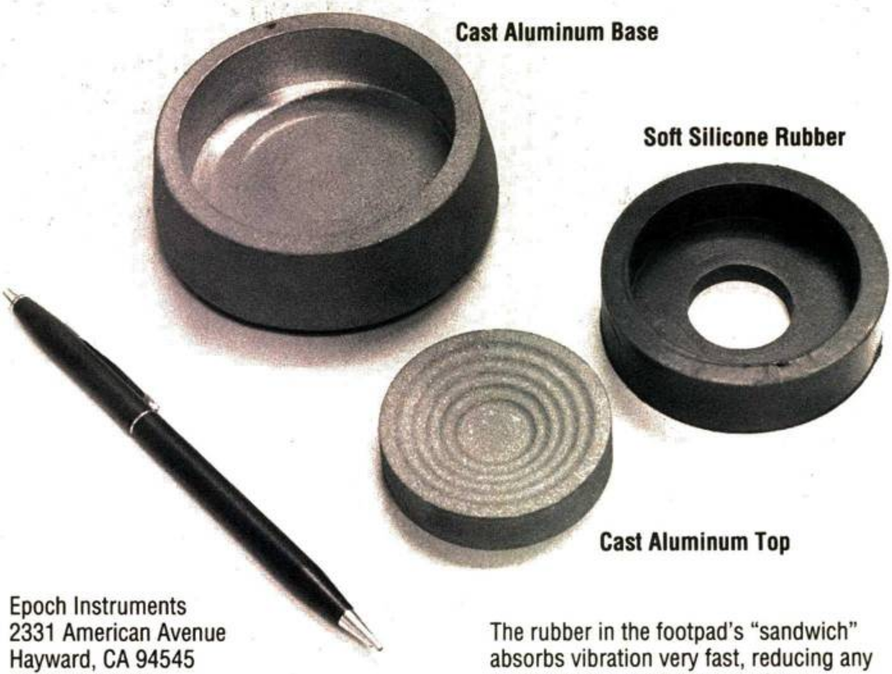
We also checked out Epoch Instruments' recommendation that you remove the rubber tips from the telescope's tripod, if it has them, before using the Shake-Enders. The numbers show that our tests didn't uncover much difference with rubber tips or without. In fact, the small variation we found indicates the opposite of what the company recommends. Nonetheless, it is possible that with a different kind of tripod tip, removing the rubber end cap might make a noticeable improvement. The simplest approach for any telescope user is to perform a quick test to see what works best with his or her instrument.

Are Shake-Enders worth the price? (They cost about the same as a good quality eyepiece.) This type of question seldom has a hard and fast answer, since everyone has a different idea of what a "reasonable" expense is. If the vibrations in someone's telescope damp out in one second or less, then in our opinion a set of Shake-Enders is unnecessary. On the other hand, if a telescope takes longer than this to settle down after being touched, the owner should consider ways to reduce the vibration.

Before purchasing extra accessories, however, a wise telescope owner will first seek to eliminate all possible wiggles from the mounting. For ideas on what to do, see "The Mount of Gibraltar" by Rick Shaffer in the August 1988 issue. Only when the mounting has been made as mechanically rigid as possible should you start looking at accessories such as a set of Shake-Enders.

There's no question Shake-Enders work very well. If your mounting is as tight as possible and your observing still suffers from images that dance in the eyepiece every time you change focus, then you should give a set of Shake-Enders very serious consideration. ☐

Anatomy of a Shake-Ender



Epoch Instruments
2331 American Avenue
Hayward, CA 94545
(415) 784-0391

The rubber in the footpad's "sandwich" absorbs vibration very fast, reducing any image shake seen in the eyepiece.

Damping Time in Seconds

Telescope	Rubber Tips	Grass	Dirt	Asphalt
Ultima 8	On	**1** 3	**1** 3	**1** 2
	Off	**1** 7	**2** 8	**1** 7
2120/LX6	On	**2** 3	**2** 4	**1** 3
	Off	**2** 6	**2** 7	**2** 7

Boldface indicates the damping times using Shake-Enders; ordinary type shows the times without.

WE FOUND IT DIDN'T MATTER much what kind of surface lies underneath the Shake-Enders; they damped out vibrations quickly whether the telescope mounting was placed on asphalt, grass, or packed dirt.

THE ART OF SEEING

Five simple techniques will improve your eyes' performance and increase your observing enjoyment.

by Michael Porcellino

"Seeing is an art which must be learnt," said William Herschel, the most accomplished observer of all time. Herschel was right: with practice, the eye detects an increasing amount of detail in sky objects. Whether you're a beginner turning a first telescope toward the Moon or a seasoned observer searching for a supernova in a distant galaxy, knowing *how* to look is a critical part of observing.

Fortunately, the useful techniques of dark-adaptation, averted vision, proper magnification, use of a nebula filter, and binocular viewing — coupled with persistent observing — allow you to expand your capabilities as an observer. Before you know it, those dim views of galaxies and fuzzy views of planets will transform into more detailed images that are more satisfying.

The Rules of Seeing

How an observer "sees" depends largely on where his or her interests lie. Deep-sky observers tend to have well-developed vision for spotting faint light and subtle details. Planetary observers on the other hand tend to have stronger visual acuity, enabling them to discern fine detail on planets and see subtle differences in colors.

A century ago, the industrious planetary observer Percival Lowell believed that both types of vision could not exist in a single person. A series of experiments conducted in the 1980s by psychologist William Sheehan, however, disproved Lowell's hypothesis. While researching his book *Planets and Perception*, Sheehan found that an observer's ability to discern detail is independent of the ability to see faint light. The bottom line is that any observer can develop both types of vision.

An observer's visual sensitivity is his or her ability to detect faint light. A good approximate measure of visual sensitivity is an observer's limiting magnitude, the faintest star that can be seen with the naked eye or a given size telescope. The normal limiting magnitude for the naked eye under a reasonably dark sky is about 6. The limit for a telescope depends on the size of the aperture. But whether or not you see a given magnitude depends on a number of factors, including atmospheric conditions, sky brightness from light pollution, your eyesight, how well you are dark adapted, how tired you are, and the quality of your telescope's optics.

To check on how your visual sensitivity is developing, determine your own limiting magnitude at the site you typically observe from. Keep a list of limiting magnitudes reached on various nights with both naked eye and a telescope. To determine your naked eye limit, use a star atlas that shows stars down to 8th magnitude or so and a good star catalog. Star atlases "bin" stars of closely equal brightness into similar size dots, but you'll want to know the exact magnitudes of the faintest stars you can see, down to one-tenth of a magnitude. To do this, use the star catalog to look up the stars you've found on the map. I recommend *Sky Atlas 2000.0* and its companion volume *Sky Catalogue 2000.0.*

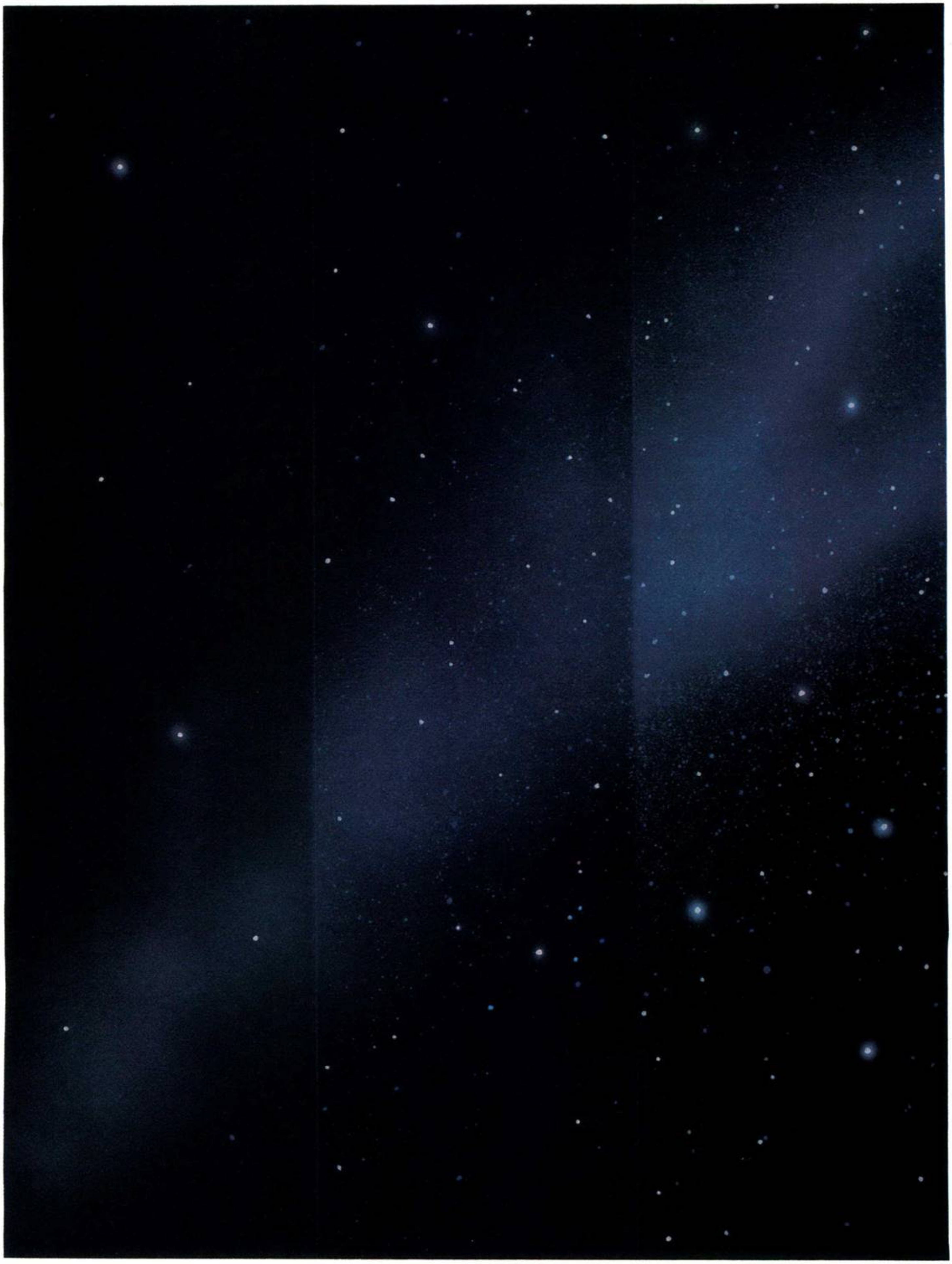
Select an area of sky that is near the zenith and not too crowded with stars. Select a few target stars but don't start with the faintest you can see. Try picking out a few third- or fourth-magnitude stars, identify them on the atlas, and work your way down to fainter and fainter stars. Each additional star should be about half a magnitude fainter than the previous one, so you gradually work toward the faintest star visible.

Now, using both star atlas and star catalog, select a "route" to your target stars and familiarize yourself with the area around them. Make sure that you use a strongly filtered red light to check data from the books so you do not ruin your dark adaptation, or better yet have a friend read the books while you observe. Sit back and look for your first star. Can you see it? Block any extraneous light with your hands or use a small tube to sight through. Once you confirm that you've found your target, take a break and try the exercise again after a brief period. It should be easier the second time and easier still the third time. Try the next target on your list until you move down to the faintest star visible. After several nights of doing this you'll become familiar with the area of sky and the procedure will become quick and simple.

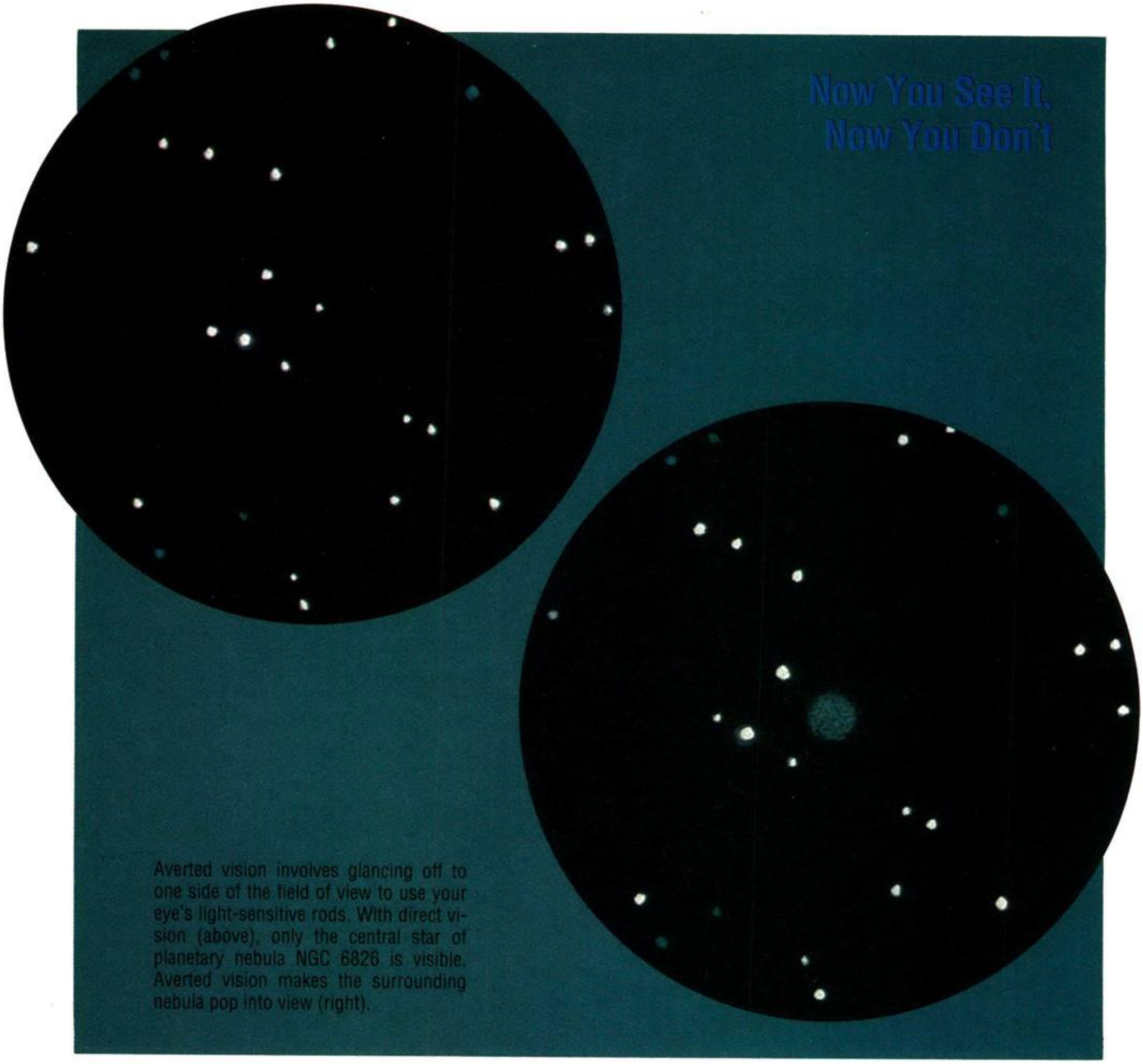
Determining your limiting magnitude with your favorite telescope is even easier. First, know that the "limiting magnitudes" given as part of the data that comes with the telescope are rough estimates at best. You're interested in determining the actual limiting magnitude and seeing how it changes over time as your eye becomes more adept at seeing.

The easiest way to estimate limiting magnitudes with a telescope is to get several charts made for estimating variable stars from the American Association of Variable Star Observers, an active group of visual observers. They sell charts showing fields surrounding hundreds of variable stars. You can use the constant stars on these charts to make your estimates. (For ordering information, send a self-addressed, stamped enve-

PROPER DARK ADAPTATION is important. After five minutes outdoors, the eye is relatively insensitive (left), but fifteen minutes' in the dark dramatically improves sensitivity (center). Dark-adapting for forty minutes maximizes the eye's sensitivity (right).



Now You See It, Now You Don't



Averted vision involves glancing off to one side of the field of view to use your eye's light-sensitive rods. With direct vision (above), only the central star of planetary nebula NGC 6826 is visible. Averted vision makes the surrounding nebula pop into view (right).

lope to the AAVSO, 25 Birch Street, Cambridge, MA 02138.)

The same rules apply to this exercise as to the naked-eye exercise. Take adequate time to prepare. Choose a couple of targets and select as the first one a star that's well within the capability of your telescope. Start by finding that star, confirming its magnitude on the AAVSO chart, and then look for fainter stars.

As you progress, study the chart carefully and know exactly what you're looking for. At the telescope use a dark cloth to cover your head so that extraneous light doesn't reduce your ability to see faint stars. Look carefully for the target stars and concentrate. Once you find one or two, take a break and relax before moving on to the next. With some practice, you'll probably find that you surpass the advertised theoretical limit of the telescope.

When you observe a faint object, you receive light signals on the eye receptors called rods. These are distributed about the edges of your retinas and are very sensitive to faint light and motion. In the centers of your retinas, however, are bright light and color receptors called cones. To maximize your ability to see faint details, use a technique called averted vision. By looking off to the edge of the field of view you use great numbers of rods to receive signals from whatever lies in the center of the field. This helps bring out details that might be invisible or more difficult to see with direct vision.

An observer's ability to see fine detail depends in part on how the cones are distributed across the retina. Compared with the rods, the cones are not very sensitive to light and require a strong signal to trigger a response. Because they are concentrated in the fovea centralis, they are perfectly placed to receive bright signals because they are at a place where incoming light forms a sharp, bright image.

We see detail because the incoming image is spread out over the cones in much the same way an image is spread out over a television screen. What you see on the TV is not a continuous image but a series of dots fired from the set's electron tube that appear to form a combined image when displayed on the screen.

Detail exists on the screen because the dots are displayed in various colors and intensities. The resolution of the screen and the amount of detail you are able to see depend on the number of dots that compose the screen and the distance between them. The more dots on the screen, the closer together they are and the better the resolution of the image.

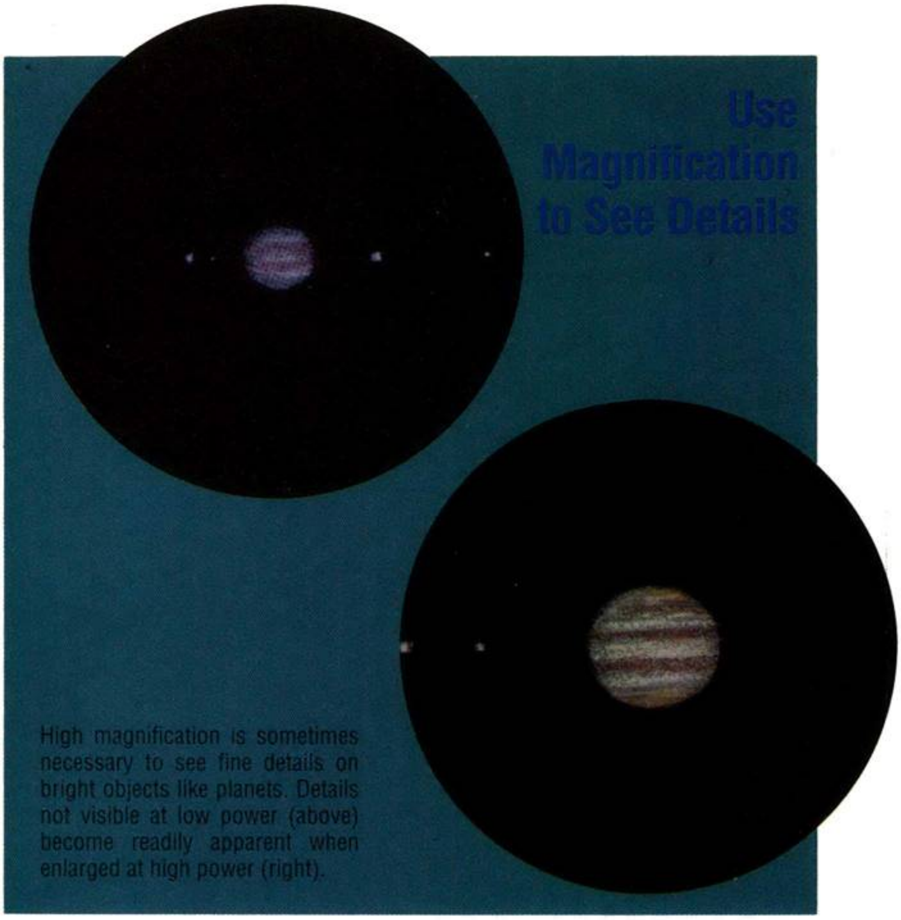
Vision itself works in much the same way. The image delivered by the eye falls onto a "screen" of cones. The resolution of the image received by the eye depends on the number of cones stimulated by a signal. The cones then transmit that signal to the brain. While some individuals may have more than an average share of cones, most of us have to make do with a "screen" of about six million cones. The best theoretical resolution that can be expected would be the distance between two individual cones, about 0.00015 millimeters, which translates to about 20 arcseconds. But the eye is not a perfect instrument and the realistic threshold of naked-eye resolution is about 60 arcseconds.

Another factor in detecting detail is contrast. Simply put, contrast is the difference in brightness, tone, or color between two adjacent objects. Differences in contrast between features allow us to see detail. The big dark feature Syrtis Major on Mars appears dark green not because it is green vegetation, as was once thought, but because of the contrast difference between Syrtis Major and the much lighter tone of the surrounding desert. This makes Syrtis Major appear extraordinarily dark.

There are a number of ways to increase image contrast. If you use a low magnification you maximize the contrast between an object and the sky background. This is why many nebulous objects are best viewed at low magnification and seem to "disappear" when viewed at high powers. Another effective method to enhance contrast is to use filters. Light-pollution filters can really help out urban or suburban deep-sky observers because they block light pollution while allowing nebular light to pass through, thereby boosting the image contrast immensely. For the Moon and planets, colored filters also work effectively to boost contrast. By allowing only a certain limited range of colors to enter the eye, specific colored features on planets stand out better from the background. Increased contrast means better visual acuity.

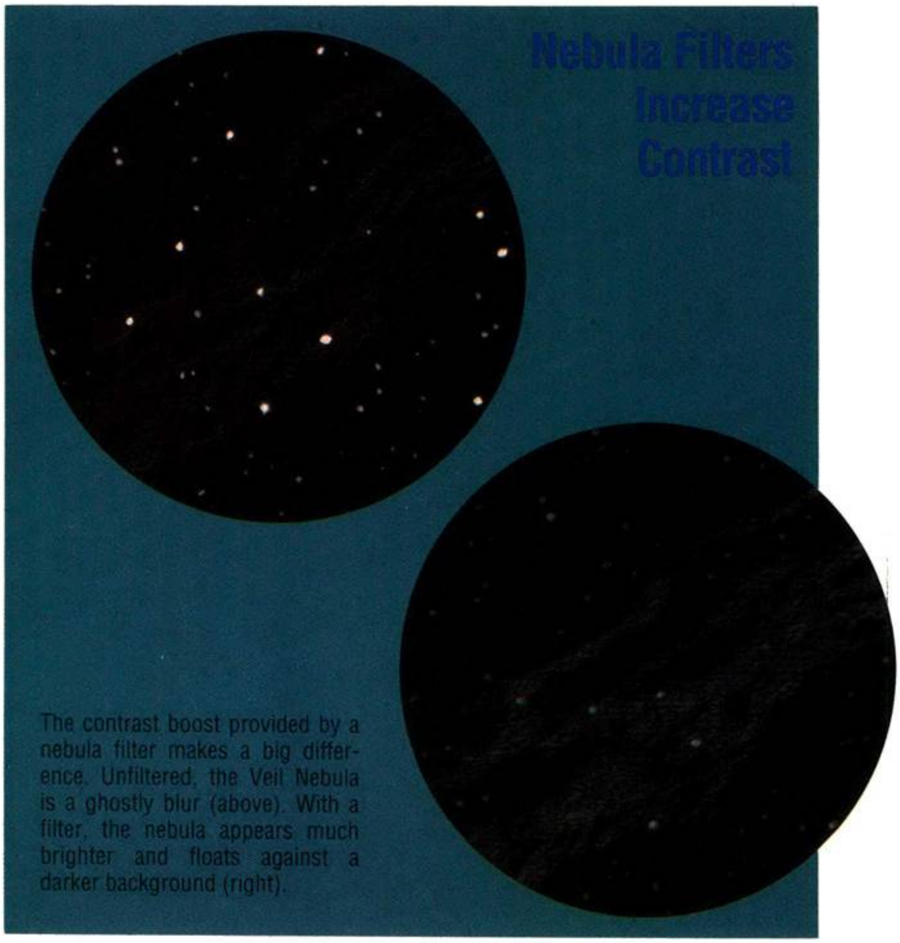
One of the significant benefits of using a telescope is that the object

Use Magnification to See Details



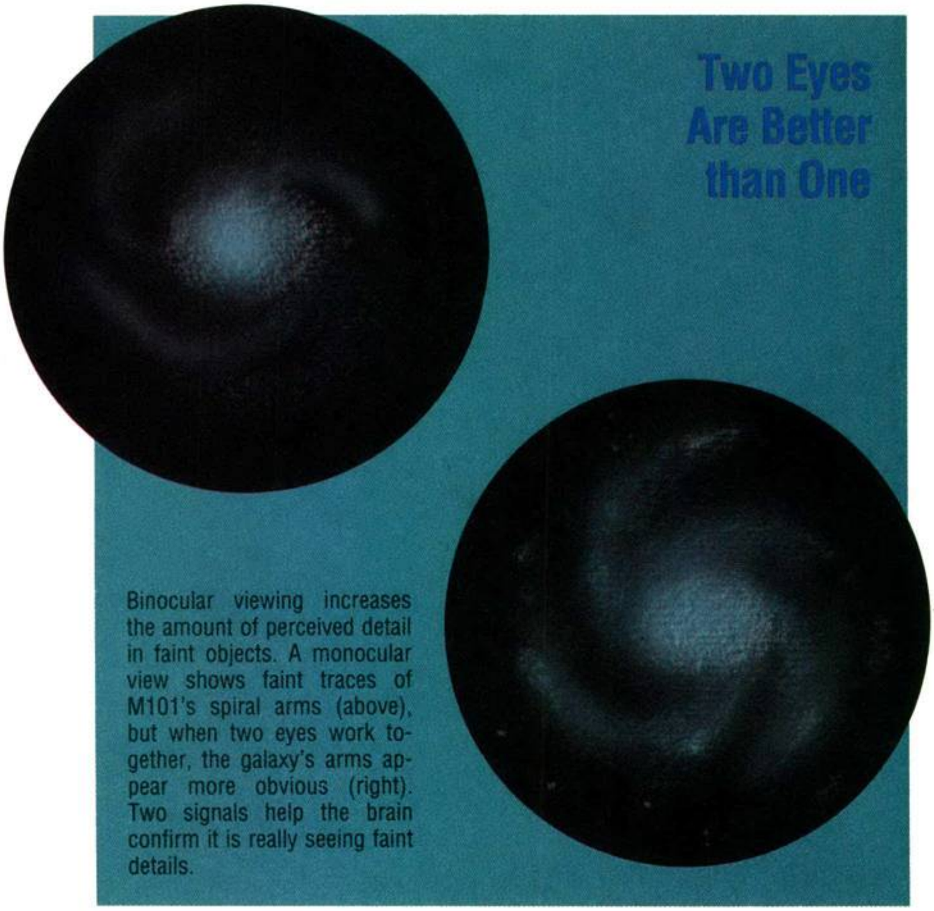
High magnification is sometimes necessary to see fine details on bright objects like planets. Details not visible at low power (above) become readily apparent when enlarged at high power (right).

Nebula Filters Increase Contrast



The contrast boost provided by a nebula filter makes a big difference. Unfiltered, the Veil Nebula is a ghostly blur (above). With a filter, the nebula appears much brighter and floats against a darker background (right).

Two Eyes Are Better than One



Binocular viewing increases the amount of perceived detail in faint objects. A monocular view shows faint traces of M101's spiral arms (above), but when two eyes work together, the galaxy's arms appear more obvious (right). Two signals help the brain confirm it is really seeing faint details.

under scrutiny is magnified and its image is spread out over a large number of cones. This allows differences in intensity and color to fall onto more cones and be more readily resolved. But each aperture has its own limit on how much it can enlarge an image, called the Dawes limit. The Dawes limit was derived experimentally and works as a good approximation of telescope resolution. But, like the formula for limiting magnitudes, it is not absolute.

The usual method of measuring visual acuity is to separate progressively closer double stars either by telescope or with the naked eye. There is a problem with this method, however. As William Sheehan demonstrated in an article in the *Strolling Astronomer*, measuring the eye's ability to separate double stars is more a test of rod vision than conal vision needed to see detail on a planetary surface. In his experiments Sheehan found that using the traditional method verified Lowell's contention that visual sensitivity and acuity could not "coexist" in the same observer. But when Sheehan switched to visual acuity as measured by a subject's ability to read newsprint at a distance, a test of conal vision, he found the results no longer supported Lowell's claim.

The ultimate test of an observer's visual acuity is the amount of detail he or she can detect. A peek at the drawings produced by experienced observers show that they are seeing a great amount of detail not visible to beginners. How can this be? Do experienced observers develop more cones in their retinas and therefore see more details?

If you ask old timers why they see so much detail on the disk of a planet, chances are they'll tell you they don't really know. What they aren't telling you is that they are seeing with "experienced eyes." Over the course of many observing sessions their minds have developed the ability to interpret detail from a "noisy" image. They see more detail in a planetary image because they have trained their minds to see more. How can you learn this trick of the trade?

Observing on a regular basis is the first step to improving your visual acuity. Take the time to familiarize yourself with your target and its features. Be patient at the eyepiece and look at your target with an open mind. Wait for the atmosphere to settle and during those fleeting moments of crystal clarity look at the target with your knowledge in mind. If you have learned the background material well, you'll know the difference between a column and a festoon on Jupiter and the Hellas Basin and Solis Lacus on Mars. Each time you approach the eyepiece, the added experience you gain will increase your visual acuity.

The Psychology of Seeing

Seeing involves more than the eye. A large part of the visual process is how the brain interprets the visual signals sent to it by the retina. "True seeing," according to William Sheehan, "is not with the eye but with the mind." Images must pass an internal filter that influences what the observer sees. Personal biases that can prejudice observations can be caused by previous observations, photographs or drawings you have seen, or other aspects of your background.

Planetary studies are particularly susceptible to these preconceptions. In many cases experienced observers see what they expect to see. The major problem for planetary observers is simple: "The details of the constantly fluctuating planetary disk become sharp for only brief interludes," says Sheehan. He further points out that "the observer has to be prepared and selective" when it comes to recording details seen on planetary surfaces. This selectiveness can cause problems. Observers bring preconceptions to the telescope and, according to Sheehan, the image's "interpretation [is] inextricably and unavoidably melded together with the recording" of the image.

If you are interested in deep-sky work, consider binocular viewing. When the mind sees two signals coming from a faint object, it is much more likely to believe what it's seeing and create a mental picture of faint details in the object. There really is something to be gained in viewing with both eyes.

Regardless of where your astronomical interests lie, practice always makes perfect. The more you observe and the more you employ techniques like dark adaptation, averted vision, proper magnification, filtration, and binocular vision, the better your observing will become. As the days and weeks pass, you'll see that there is a lot more to *seeing* than just seeing. ☐

Michael Porcellino is an active observer living in Chicago. His first book on astronomy, Through the Telescope, *was published in 1989 by TAB Books.*

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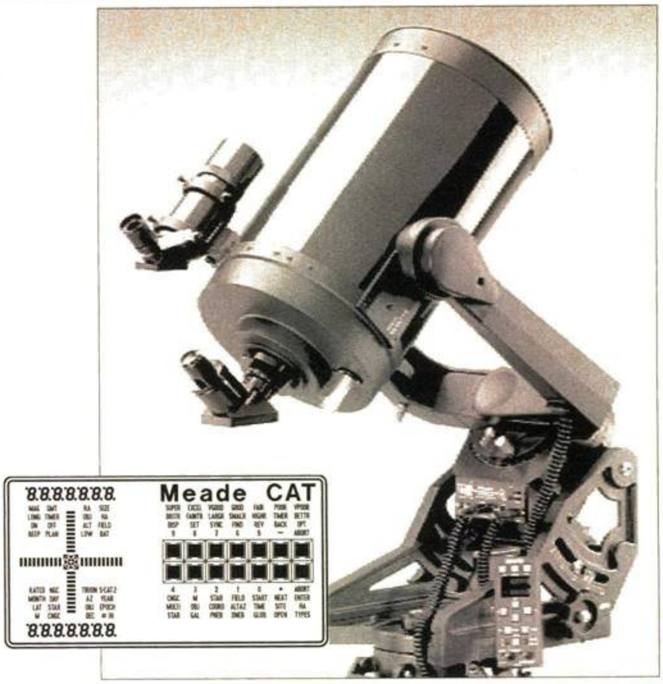

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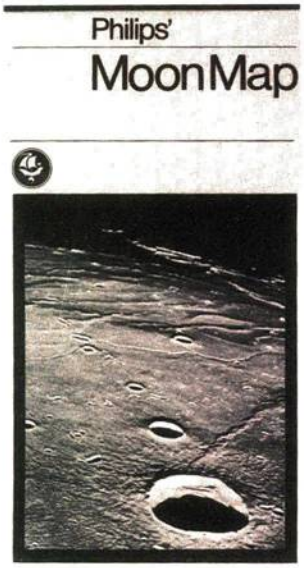

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Find a Supernova Remnant

Careful searching with a moderate-size telescope can show the faintly glowing remains of stars that exist no more.

by Chris Schur

To see a supernova remnant is to see one of the most short-lived and tenuous of all deep-sky objects. Cosmic bubbles blown off by dying stars, they balloon into space for tens of thousands of years before becoming so thin that they are no longer visible. While tens of thousands of years is a long time by human standards, it is but a moment in the history of the universe. As deep-sky objects go, observing supernova remnants is an extreme challenge. Their low surface brightnesses mean that even relatively close, young supernova remnants are difficult to spot. And as they get older their surface brightnesses plunge.

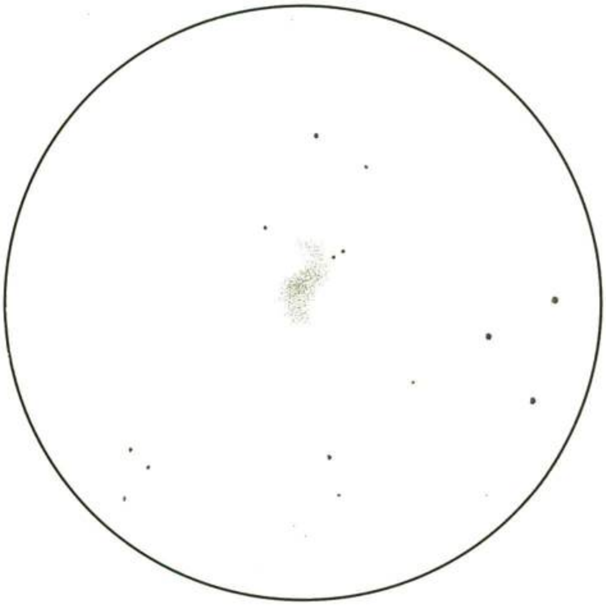
Supernova remnants result from the most violent events in the universe, save for the Big Bang itself. When an extremely massive star runs out of material for nuclear fusion, it begins a process that leads to internal collapse and finally an enormously powerful explosion. The energy released during this explosion can equal the total output of one hundred million Suns. The supernova can, briefly, outshine an entire galaxy.

The most easily observed supernova remnant is the **Crab Nebula** in Taurus, catalogued as M1 and NGC 1952. The Crab is the result of a supernova explosion that occurred just 900 years ago. (The event was observed in A. D. 1054 by Native American skywatchers and meticulously recorded by Chinese astronomers.) It lies at a distance of about 6,300 light-years and is only a few light-years in diameter.

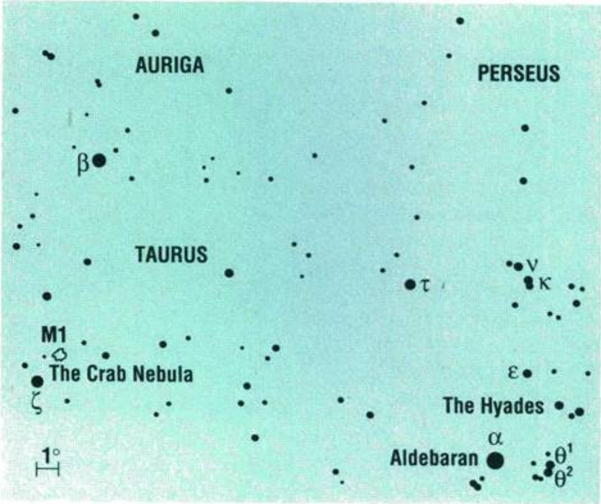
The Crab Nebula was discovered telescopically by the English amateur astronomer John Bevis in 1731. All that is left of the once mighty progenitor star is a 16th-magnitude pulsar, rapidly spinning 30 times a second.

To find the Crab Nebula, start by locating the bright star Zeta (ζ) Tauri. Now move slightly over 1° northwest and you'll see the Crab centered in the field.

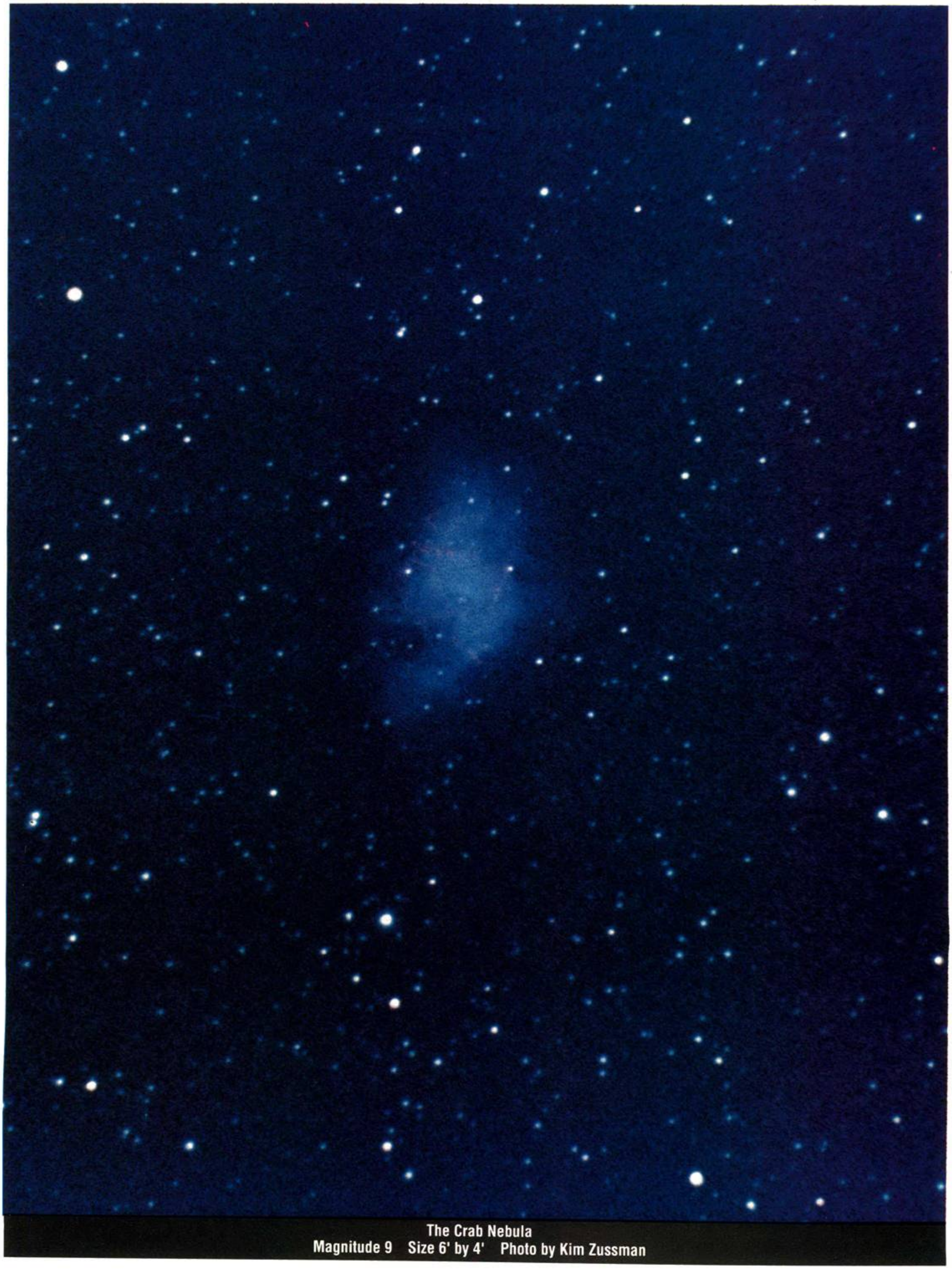
At about 9th magnitude the Crab is faintly visible in large binoculars as a tiny patch of gray-green light. Small telescopes reveal much more of the nebula's shape, which is more or less oval with some irregular mottling around the edges. An 8-inch telescope at 50x reveals an irregularly shaped, elongated nebulosity measuring about 6' by 4' situated in a rich star field. In a 12-inch scope or larger you may see variations in brightness inside the nebula and also intricate patterns of fine, linear streaks of nebulosity across the face of the object. These are the brightest of the Crab's filaments, glowing spikes of material that condensed after the explosion.



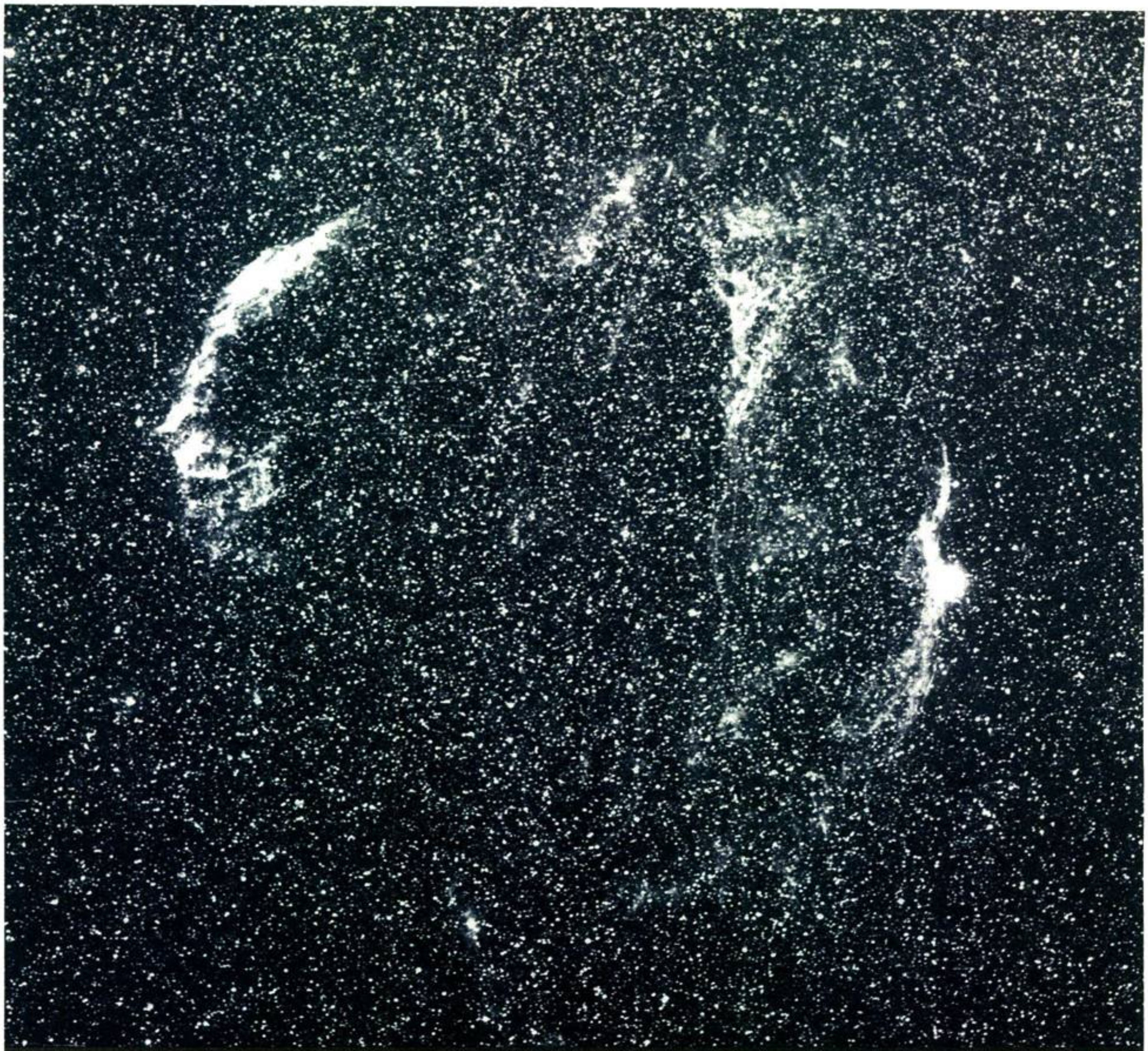
The Crab Nebula
8-inch f/10 SCT at 100x   Sketch by Chris Schur



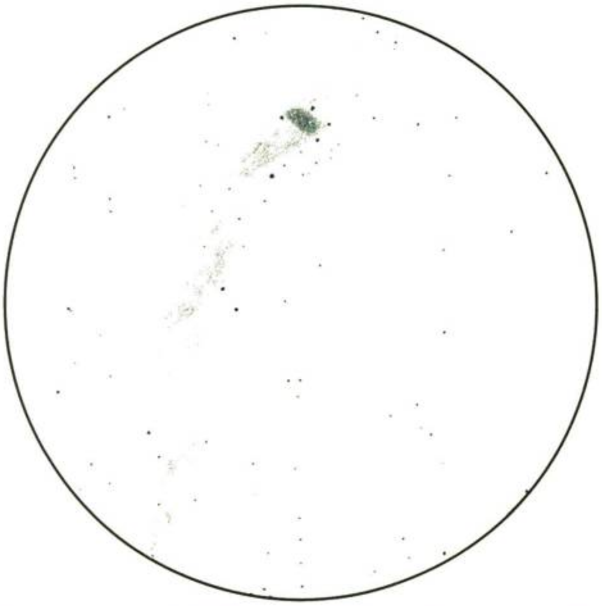
THE CRAB NEBULA is the brightest supernova remnant in the sky. It is located 1.5° northwest of Zeta Tauri.



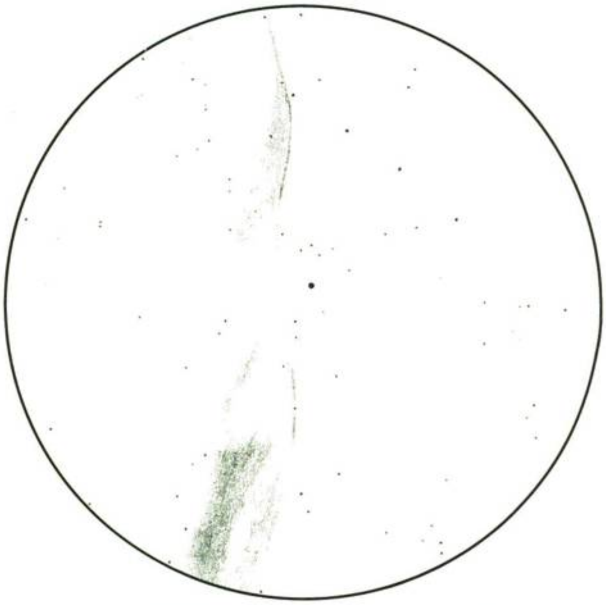
The Crab Nebula
Magnitude 9 Size 6' by 4' Photo by Kim Zussman



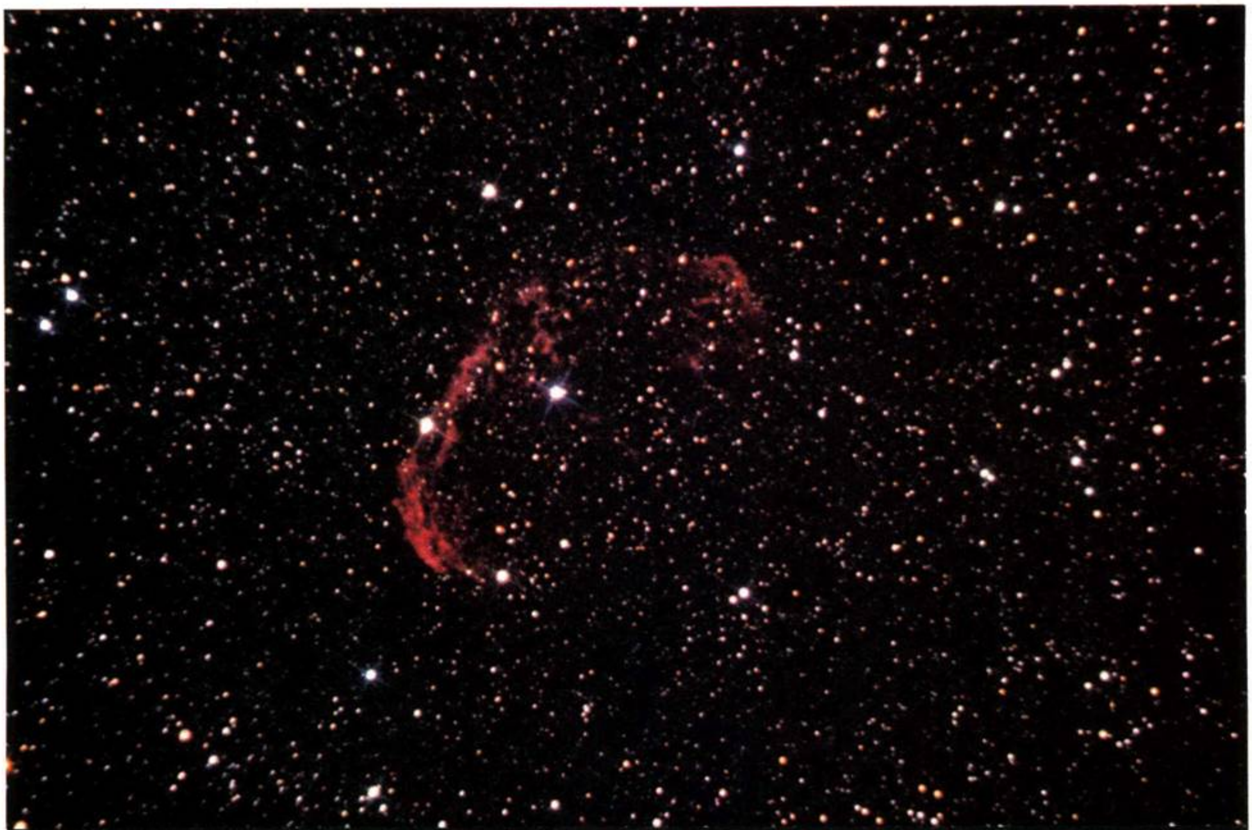
The Veil Nebula
Sizes 70' by 6' (NGC 6960) and 60' by 8' (NGC 6992-5) Photo by Chris Schur



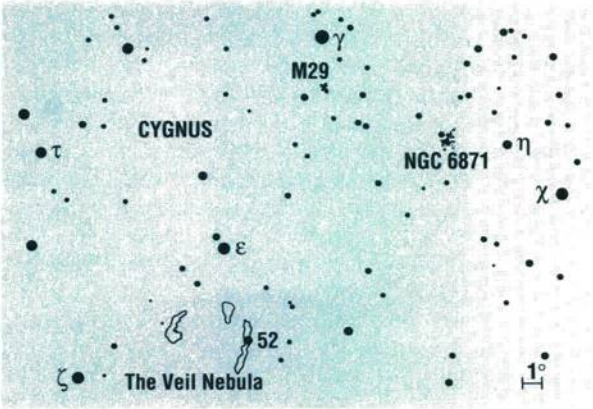
NGC 6992-5
16-inch f/4.4 reflector at 90x Sketch by Rick Rotramel



NGC 6960
16-inch f/4.4 reflector at 90x Sketch by Rick Rotramel



NGC 6888
Size 20' by 10' Photo by Scott Hicks



GHOSTLY SHELLS OF LIGHT, the Veil Nebula and NGC 6888 are both challenging targets. Nebula filters enhance their faint glows and make them appear brighter.

Because most supernova remnants cover at least a degree, observing them requires a wide-field eyepiece. The large exit pupils provided by these oculars render bright and contrasty images that enable you to see faint detail. Nebula filters allow you to boost the contrast between an object and the sky background further by transmitting the nebular light and cutting out light pollution. The result is a darker sky background that makes the nebula appear to "pop."

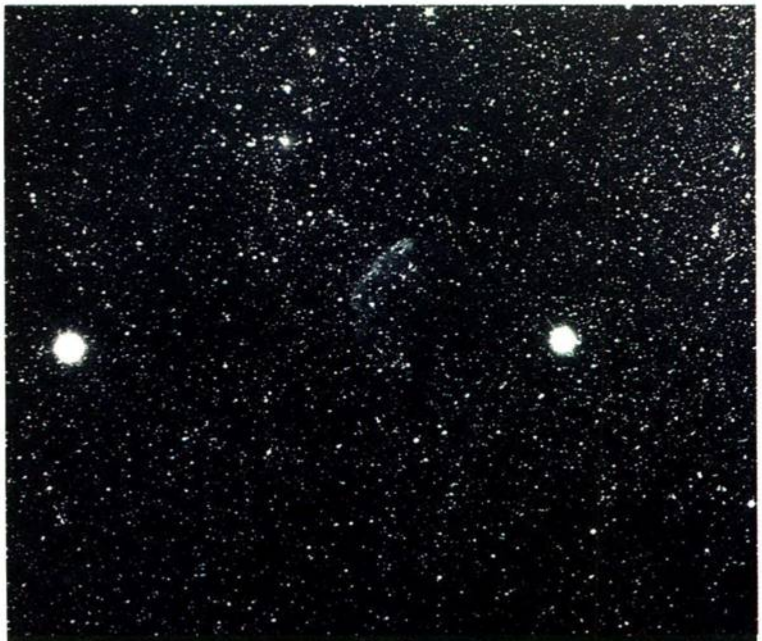
This contrast enhancement is crucial for spotting supernova remnants since much of their light is only slightly brighter than the sky background itself. To maximize your view of faint details, slowly nudge the telescope's tube back and forth as you try to pick out detail in the nebula. This helps bring out details that may be missed in a stationary view because your eyes are especially sensitive to motion when viewing faint light.

An object much improved by field sweeping is the **Veil Nebula** in Cygnus, one of the largest supernova remnants. Discovered in 1784 by William Herschel, the Veil Nebula is all that remains of a supernova explosion that occurred some 30,000 or 40,000 years ago. Located 2.5° south of the bright star Epsilon (ε) Cygni, the Veil spans some 2.6°, which equals 70 light-years at its distance of 1,500 light-years.

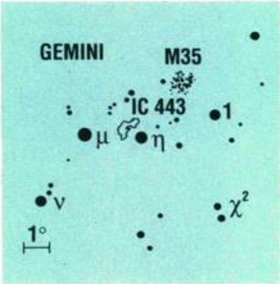
The Veil Nebula is one of the most detailed objects in the sky. Consisting of two bright, narrow components and a faint triangular patch, the Veil appears dim because its light is spread over such a large area. A wide-field rich-field telescope under a moonless sky may show the entire Veil Nebula as an extremely faint oval of gray light some 2° in diameter. However, the oval appears incomplete; only the eastern and western edges are clearly defined.

Large telescopes show the individual parts of the Veil Nebula. The easiest segment to find is NGC 6960, a long, thin arc of nebulosity oriented north-south that is bisected by the bright star 52 Cygni. Six-inch telescopes reveal traces of this object, although a 10-incher is required to see the object's knotty detail, which resembles twisted strands of rope glowing with an eerie light. The eastern section, NGC 6992-5, is brighter and considerably more detailed than NGC 6960, but it is more difficult to find.

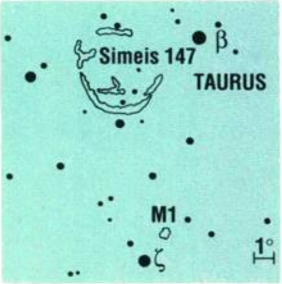
To locate NGC 6992-5, sweep about 2° due east of 52 Cygni. Both NGC 6960 and NGC 6992-5 measure approximately 65' by 7'. Lying between the two bright sections is a much more challenging object, the triangular nebula NGC 6979. This object is not easily



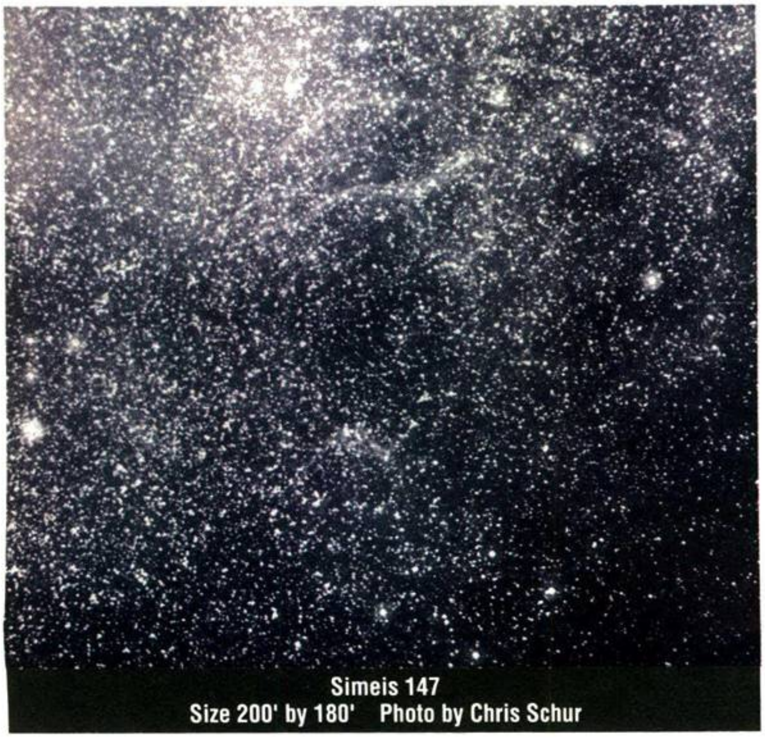
IC 443
Size 50' by 40'   Photo by Chris Schur



IC 443 IN GEMINI appears as an extremely faint loop of gray light in large telescopes.



THE ULTIMATE CHALLENGE in photographing supernovae is Simeis 147.



Simeis 147
Size 200' by 180'   Photo by Chris Schur

Supernova Remnants for Backyard Telescopes

Object	R.A. (2000.0) Dec.		Mag.	Size
M1 (NGC 1952)	5h34.5m	+22°01'	9	6' by 4'
Simeis 147	5h39.1m	+28°00'	—	200' by 180'
IC 443	6h16.9m	+22°47'	—	50' by 40'
NGC 6888	20h12.0m	+38°21'	—	20' by 10'
NGC 6960	20h45.7m	+30°43'	—	70' by 6'
NGC 6992-5	20h56.4m	+31°43'	—	60' by 8'

Object: Messier, NGC, or other catalog designation. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** Approximate V magnitude of nebula. **Size:** angular extent in arcminutes.

visible with small telescopes but can be spotted on a dark night with a 10-inch scope.

Also in Cygnus is the more challenging supernova remnant **NGC 6888**, located in an extremely crowded star field about 3° southwest of Gamma (γ) Cygni. This object is an oval nebulosity measuring 18' by 12' and is a challenging test for an 8-inch telescope.

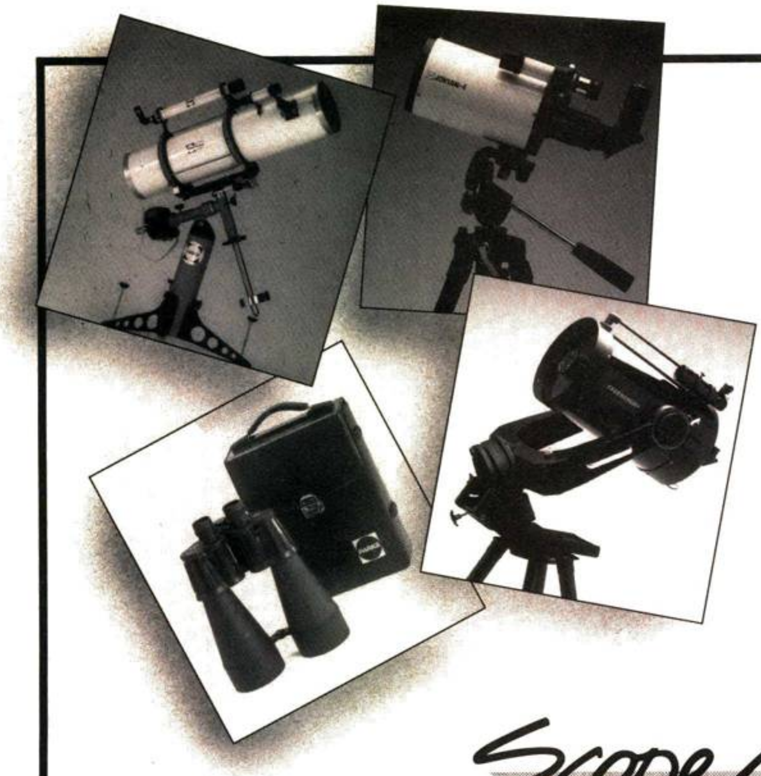
Two progressively more difficult supernova remnants lie in the winter sky. Located just 3° southeast of M35, **IC 443** can be glimpsed in a 10-inch scope equipped with a good nebular filter. At a distance of 10,000 light-years, this object has a much lower surface brightness than the Crab or the Veil. About the same age and size as the Veil, IC 443 is also circular in form. Unlike the Veil, however, IC 443 expanded into a nonuniform interstellar medium and is much brighter on its eastern side.

The eastern portion is the part you can see in backyard scopes. To spot it, sweep about a degree east of the 3rd-magnitude star Eta (η) Geminorum. In a low-power ocular it appears as a 25' by 5' arc of nebulosity, glowing faintly against the sky background. Even the largest scopes show little more, as most of the fine structure in this nebula is either too faint to be seen or smaller than an arcsecond in width.

Some supernova remnants are too faint to see by eye. Here, the power of photography serves to reveal these objects. Located just 5° north of the Crab Nebula is **Simeis 147**. At a distance of about 1,500 light-years, S147 is very close as such objects go. Although comparable to the Veil Nebula in size, it is much fainter and has, as far as I know, never been seen visually. However, it remains a challenge to backyard astrophotographers who wish to capture the extremely faint wisps of light from this tenuous object. I've found that hypered Tech Pan and a deep, filtered exposure successfully record the brightest parts of this extremely difficult object.

Hunting supernova remnants requires patience, persistence, and a very dark sky. When all three factors are working together you will be able to witness the remains of nature's most violent act. That's a mind-boggling thing to think about as you gaze at a fuzzy disk of light in your telescope's eyepiece on peaceful little Earth. ☐

Chris Schur is an avid astrophotographer and observer living in Black Canyon City, Arizona.



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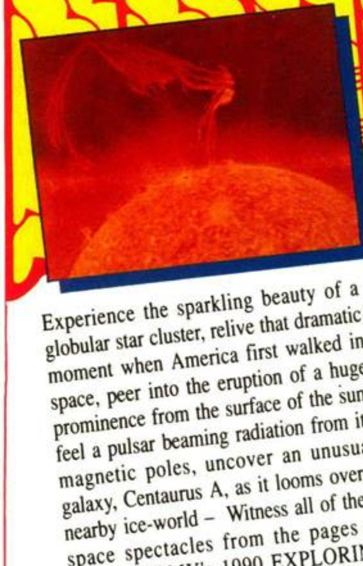

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Inside the Hyades

Our proximity to the famous Hyades Cluster lets you view a star cluster close up.

by Edmund A. Fortier

The winter Milky Way rises out of Monoceros in the south like tenuous chimney smoke, sweeps between Gemini and Orion as it brushes the horns of Taurus, drifts into Auriga, and then descends to the northwest horizon through Perseus, Cassiopeia, and Cepheus. Conspicuously absent are the billowing starclouds and dark rifts that distinguish the summer Milky Way. In winter our view is in the opposite direction, toward the sparser outer regions of our galactic neighborhood.

One of the more beautiful winter open clusters is the Hyades. At a distance of 147 light-years, the Hyades is the second-closest open cluster (the nearest is the Ursa Major moving group, which consists mainly of the Big Dipper), the core of which comprises the well-known V-shaped asterism in Taurus.

On the one hand, the Hyades is a fairly typical star cluster. With an estimated age of 660 million years, it falls about midway between the youngest and oldest of all such groups. Most of its 350 members are stars like the Sun; there are no young, hot O- or B-type stars, only a few red giants, and about a dozen white dwarfs.

But the Hyades also affords backyard observers the unique opportunity to explore an open star cluster close up. Over two-and-a-half times closer than the Pleiades, the core of the Hyades spans more than 5° of sky. Although the naked eye may interpret the Hyades as a fairly concentrated grouping of stars, this impression vanishes with the slightest optical aid. A small telescope allows you to explore the cluster virtually from the inside out.

To begin exploring the Hyades, look first at the V-shaped asterism that outlines the muzzle of the Bull. The northern arm consists of six stars extending from Gamma (γ) Tauri, which marks the apex of the "V," to Epsilon (ε) Tauri, just over 4° away. Magnitude 3.6 Gamma is one of the Hyades' four prominent red giants (spectral type K0).

At magnitude 5.6, the next star, 63 Tauri, is the faintest component of the arm. Though the Hyades abounds in double stars, these two are solitary suns and visually unremarkable. However, if viewed together in the same binocular field, they provide a subtle contrast in color: Gamma possesses a yellow-orange hue while 63 Tauri shines pure white.

Situated about half-way along the arm is a pair of 4th- and 5th-magnitude stars some 20' apart in an east-west orientation. The western star, Delta^1 (δ^1) Tauri, is the brighter of the two and a wide visual double. Look for a 12.5-magnitude companion 107" away north-northwest of the primary. Like Gamma Tauri, Delta^1 is a K0 giant. (Do their colors look the same to you?) To the east of Delta^1 lies its neighbor, 4.8-magnitude Delta^2 Tauri, also a wide double. The 13.3-magnitude companion lies 137" west-southwest of the primary. Though it is quite faint, the companion is far enough away from its dazzling primary to be within reach of moderate-size telescopes.

Just beyond Delta^2 lies 4th-magnitude Delta^3 Tauri. A triple system, its two companions shine at magnitudes 7.5 and 8.7 and lie 1.4" northwest and 77" southwest of the primary, respectively. You will need moderate to high magnification and excellent seeing to resolve the close pair. Delta^3 is slightly variable, and its A2 spectrum makes it one of the hottest and brightest of the Hyades' stars, except for the giant members. With a mass and diameter approaching three times that of the Sun, its luminosity is almost fifty times as great.

Lying 1.5° to the northeast, Epsilon Tauri is the last star in the northern branch of the Hyades and the third giant of spectral class K0. It too is a telescopic double: the primary is magnitude 3.5 while the companion, lying 182" due west, is magnitude 10.5.

The southern arm of the "V" is visually the more interesting of the two. Here you'll find both the brightest and faintest of the naked-eye Hyades as well as several impostors. Of course, not every member of the Hyades demands close scrutiny. Located almost 2° east of Gamma is 4th-magnitude 71 Tauri. A solitary sun, this object has little to offer backyard observers. However, it does point the way to one of the cluster's most attractive members.

Put your telescope aside for a moment and look closely at the star just to the east-northeast of 71 Tauri. If the atmosphere is steady, you should be able to split this wide double without optical aid. Designated Theta^1 (θ^1) and Theta^2 (θ^2) Tauri, the two components are 337" apart in a north-south orientation. The northern star, Theta^1, shines at magnitude 3.8 and is yet another giant of spectral type K0. How does its hue compare with the others?

With a luminosity some fifty times that of the Sun, Theta^2, a magnitude 3.4 giant, is the brightest member of the Hyades. Although Theta^1 is a half-magnitude fainter, both stars appear equally brilliant in binoculars or a low-power eyepiece. Astronomers think Theta^2 may be a Delta Scuti-type variable. Although similar in some ways to their cousins the Cepheid variables, these stars are intrinsically far less luminous and are characterized by incredibly small and rapid variations in brightness. Theta^2, for example, fluctuates by a

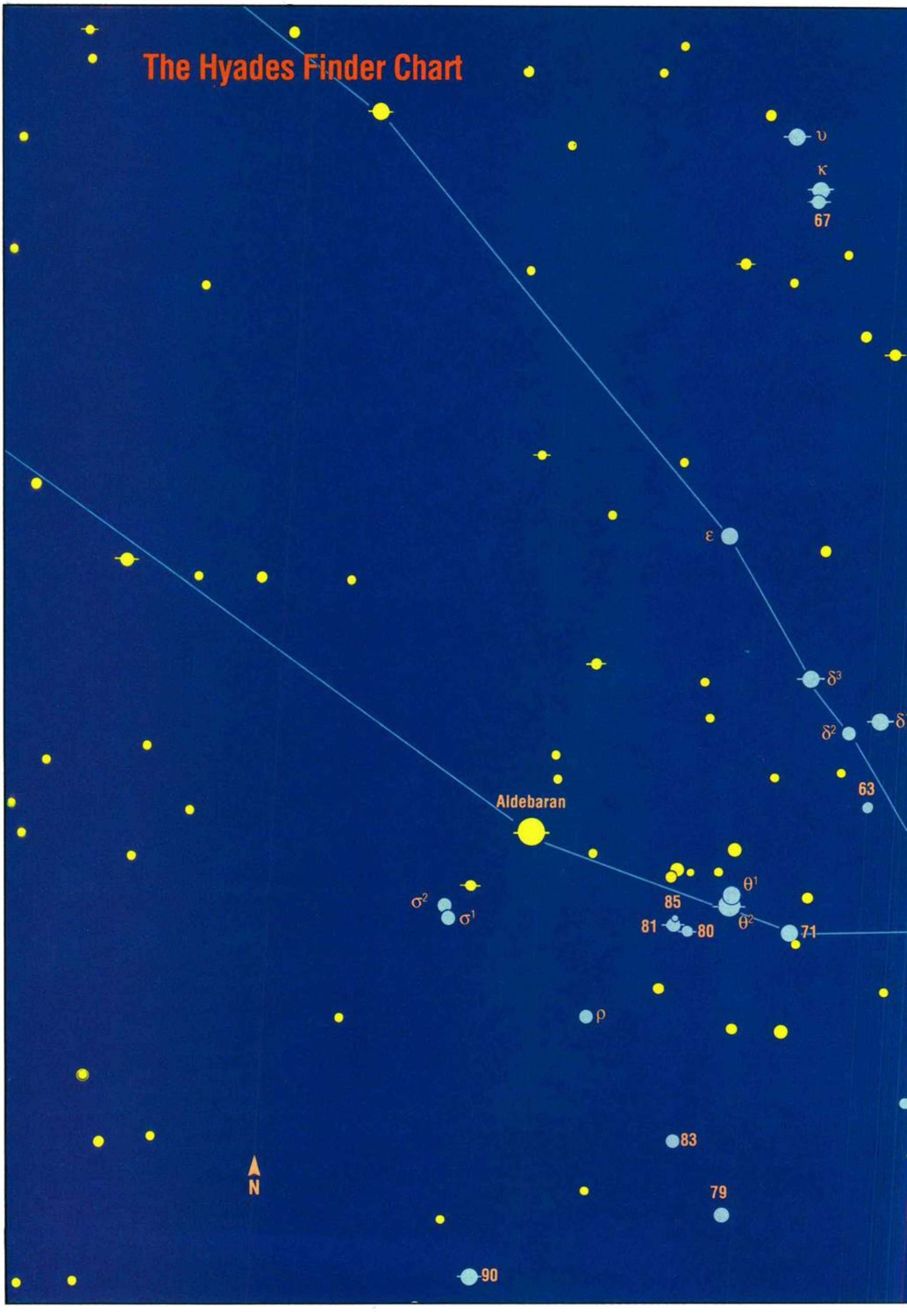
THE V-SHAPED HYADES is a distinctive asterism in the winter sky that's well worth exploring. Photo by Jeff Kanipe.

visually imperceptible 0.03-magnitude about every two hours. The 5th-magnitude star just to the north of the two Thetas is a background object and not a cluster member.

Turn next to the three faint stars that lie between Theta^2 and Aldebaran. The first of these is 80 Tauri, a visual binary with a period of 190 years. This is another difficult double to split. The difference in magnitude between the two components (5.7 and 8.0) combined with only a 1.7" separation demands high magnification and very good seeing. Look for the companion just north of the primary.

Much easier to resolve is the middle star, 81 Tauri. Though its components shine at magnitudes 5.5 and 9.4, the distance between them is a spacious 162" in a north-northwest orientation. Expect the secondary, a K0-type sun, to glow with a golden tint. The last of the three, 85 Tauri, is a solitary star. At magnitude 6.0, it borders on naked-eye visibility. First-magnitude Aldebaran marks the end of the southern branch. Only 68 light-years away, Aldebaran is a foreground star and appears among the Hyades by chance.

Sometimes overlooked are those stars that belong to the Hyades Cluster but are not associated with the asterism. A sprinkling of these can be found about 6° due north of Gamma, beginning with 51 Tauri. Yet another wide double, 51 Tauri's components are magnitudes 5.6 and 10.8, with the companion lying 166" northeast of the primary. Now look 2° to the northeast for Kappa (κ) and 67 Tauri, a pretty sight in any low-power field. Like the two Thetas, this magnitude 4.2 and 5.3 pair is oriented north-south and separated by some 330". (These stars share the same proper motion but do not form a true double.) Unlike the Thetas, however, Kappa and 67 Tauri exhibit identical spectra (A7) but differ in brightness by a full magnitude. Upsilon (υ) Tauri, less than a degree away, is also a cluster member as



The Hyades Finder Chart

υ
κ
67
ε
δ³
δ
δ²
63
Aldebaran
θ¹
θ²
85
81
80
71
σ²
σ¹
ρ
83
79
90
N

well as a telescopic double. The primary is magnitude 4.3; the secondary shines at magnitude 12.4 and lies 104" west-northwest of the primary.

Now search for the brighter cluster members below the asterism. Half a degree southeast of Gamma is 5th-magnitude 58 Tauri, another Delta Scuti-type variable with a magnitude range slightly larger than Theta^2's. Three more cluster members — 60, 79, and 90 Tauri — curve away to the southeast. The first and third of these are triple systems, each with two faint companions; the second is a lone sun of spectral type A. About 10° south and a little west of Gamma is a double system, 45 Tauri. The 9.8-magnitude secondary lies 124" northeast of the 5.7-magnitude primary, making this a fairly easy pair to resolve.

Due west of 60 Tauri is yet a third Delta Scuti-type variable, 57 Tauri. A far more difficult double, its elusive 13.5-magnitude companion, 35" to the north, is beyond the light-grasp of small amateur telescopes. Between 79 Tauri and Aldebaran lie two more cluster members, 83 and Rho (ρ) Tauri. Rho is a single sun, but 83 Tauri is accompanied by an 11th-magnitude companion lying 112" east-southeast of the primary.

Put your telescope aside again and look carefully at Sigma^1 (σ^1) and Sigma^2 (σ^2) Tauri, a 5th-magnitude pair located a degree southeast of Aldebaran. If you were able to split the two Thetas without optical aid, these blue-white suns, separated by over 7', should present no problem. Both stars exhibit nearly identical spectra (A3 and A2) and differ in brightness by just 0.4 magnitude. Despite these similarities, this is an optical double, and only the northern star, Sigma^2, is an actual member of the Hyades.

After you have completed your survey of the Hyades, take another look at its now-familiar stars splashed across the face of Taurus. To be sure, the view does not compare with that of a rich telescopic cluster suspended in the field of a low-power eyepiece, but the reverse is equally true. No other cluster can be observed nearly as well with the unaided eye — or explored so thoroughly with just modest equipment — as the Hyades. ☐

Edmund A. Fortier is a high school teacher living in North Scituate, Massachusetts. His previous article, "Touring the Stellar Cycle," appeared in the March 1987 issue.

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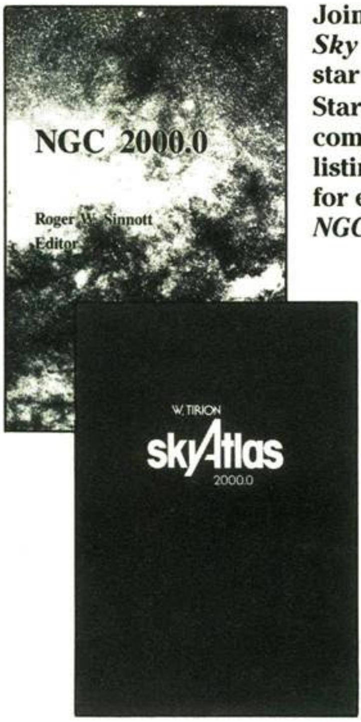

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PHOTOGRAPHING THE ACTIVE SUN

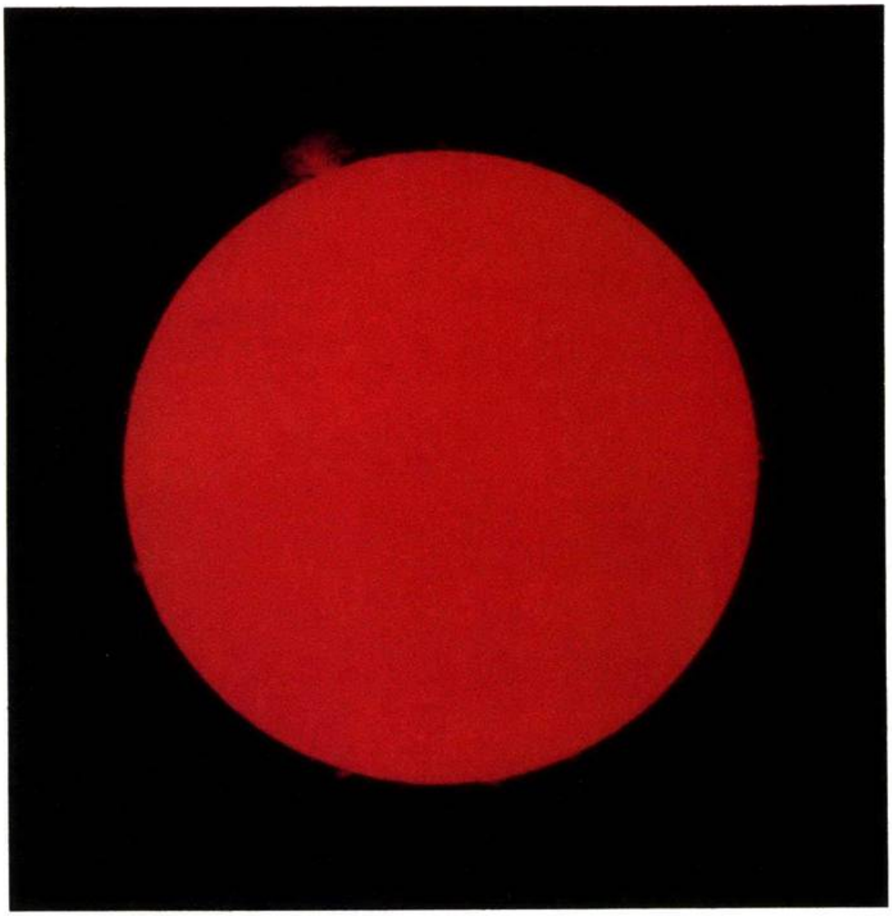
"The Sun has put on a tremendous display of activity over the past few months," said Rick Dilsizian of Mahopac, New York. Dilsizian is an avid solar photographer and is understandably excited these days. "You can go outside on any day and expect to photograph a flare, prominence, or sunspot group," said Dilsizian. "And because of the heightened solar activity, you're also likely to see a nighttime aurora that can be photographed easily with a simple camera and a tripod.

"A typical example of the outstanding solar activity," said Dilsizian, "was the passage of an enormous chain of sunspots across the solar disk in early September 1989. The chain appeared near the Sun's limb on August 30. By September 4, when the chain was centered on the Sun's disk, the diameter of the group approached 200,000 miles."

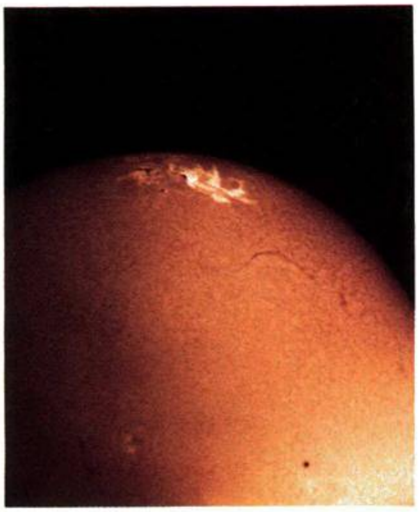
Andrew Zirschky, a solar observer from Dundee, Oregon, sketched the enormous sunspot group on September 3, 1989, with a 2-1/4-inch refractor and a solar filter. "The sunspot group was so complex," said Zirschky, "that I had to revise the sketch five times before I got it right."

Solar activity hasn't been limited to sunspots, however. Recent months have witnessed several major white-light flares and a frequent display of enormous prominences. One of the most spectacular flares occurred on October 24, 1989, and was observed and photographed by Sun watcher Bob Bona of Atchison, Kansas. "I was watching two large areas of sunspots on the Sun's western limb," said Bona, "and over the course of an hour they began to brighten. I did not realize at the time that I was watching a major flare, but fortunately I took some black-and-white photos of the area that show a bright flare. The active region that produced the flare disappeared around the limb on October 26, 1989."

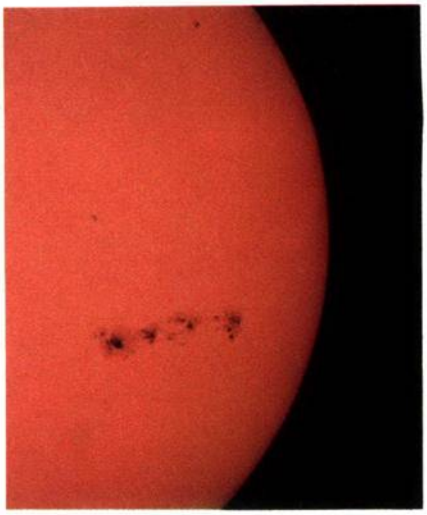
Increased flare activity means a rise in the frequency of aurorae. Michael Boschat's report of a bright auroral display on August 28, 1989, typifies the many that have been visible over the past few months. "I noticed a glow in the north that appeared pale green and contained a few rays extending 10° or so toward the zenith," said Boschat, an observer from Halifax, Nova Scotia. "Ten minutes later I saw a ray some 30° long that disappeared after about thirty seconds. The aurora continued with



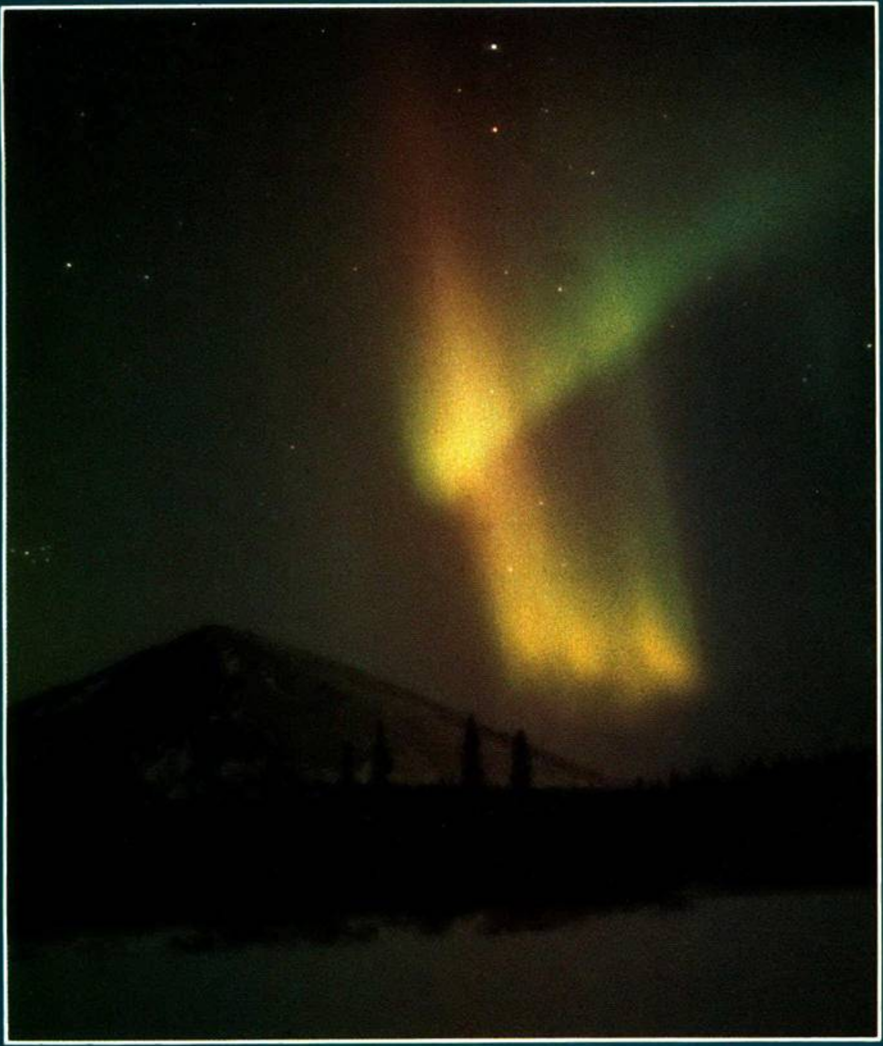
LIKE A MUSHROOM, an enormous, active prominence protrudes off of the Sun's disk on May 31, 1989. Photo by Steve Goldberg.



A WHITE-LIGHT FLARE was visible when Bob Bona photographed the Sun on October 24, 1989.



A SUNSPOT CHAIN stretched over 200,000 miles long as it rotated around the Sun during September 1989. Photo by Bill Benesch.

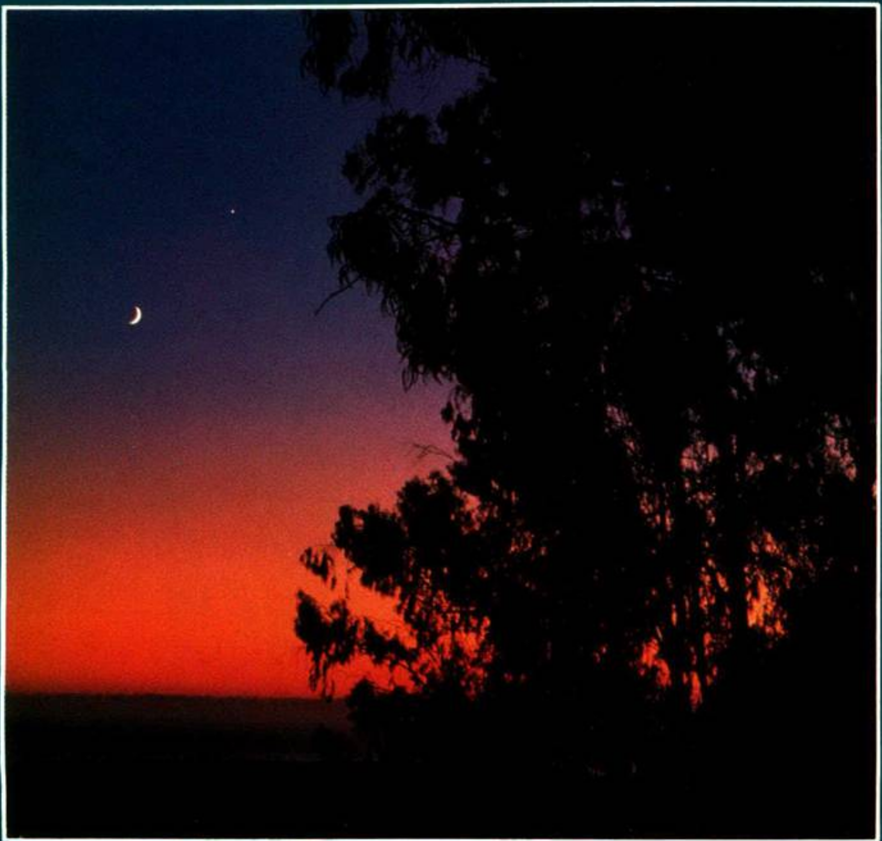


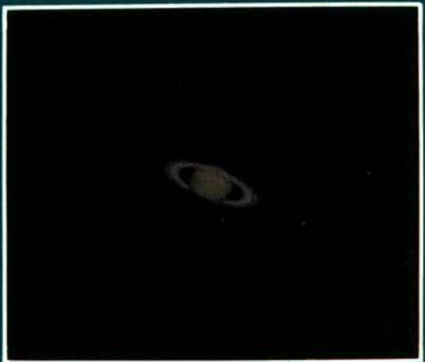
CLOSE FOCUS ON COPERNICUS

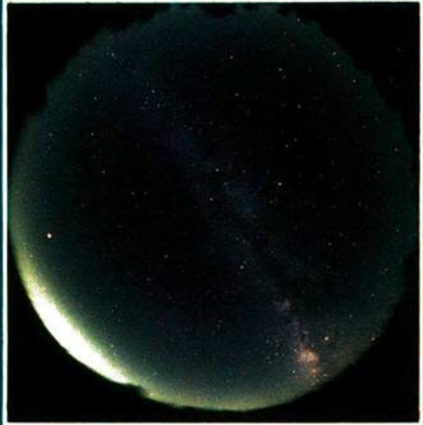
Those who try it know that lunar photography is no easy task. That's especially true when photographing details on the Moon, which requires an enormous image scale and a relatively long exposure. Christian Viladrich's high-resolution photograph of Copernicus nets this month's $100 "Best Astrophoto" award. A resident of Cahors, France, Viladrich used an 8-inch SCT at f/50 and hypersensitized Tech Pan film for the photo.

Shooting the Moon from a wider perspective was Chris Trounson's objective when he caught a conjunction between the Moon and Venus in October 1989 (bottom, left). Mars is the bright object at lower left in Mark Coco's all-sky exposure made on August 13, 1988 (bottom, right). Coco used an 8mm f/4 lens to capture the wide expanse of sky. Saturn, the most spectacular of all planets, was captured by Jean Dragesco in the spring of 1984 (below).

The recent increase in solar activity has generated interest in photographing aurorae like this one in Alaska, a spectacular event when photographed by Forrest Baldwin in 1982 (left).







slow changes in color and intensity for two hours and made me quite happy to have experienced such a great show."

THE PERSEIDS OF '89

During August 1989 the Perseid meteor shower marked the annual peak of meteor observing with as many as sixty meteors per hour at maximum. Clyde Kirkpatrick, president of the Santa Barbara Astronomy Club in California, set up early to photograph the Perseids. "On August 6, 1989, I went to the club's star party at the Winchester Canyon Gun Club in the Santa Ynez Mountains near Santa Barbara," explained Kirkpatrick. "I placed my camera on a tripod next to a chaise longue so I could lie back and watch meteors and also reach over to control the exposures. The procedure was simple: To begin an exposure I reached over, released the cable, cocked the camera, and locked the shutter open in a few seconds. The 28mm lens covered a wide field of sky so I was almost certain to record at least some Perseids."

Using the same technique on August 12, the night of the maximum, Kirkpatrick counted twenty-eight Perseids and five sporadics between 1:04 a.m. and 2:04 a.m. PDT. "When I went inside to get some sleep," said Kirkpatrick, "my wife Jean woke up and wanted to see some meteors. We went outside and counted sixty-three meteors over the course of the next hour."

MEMORIES OF THE LUNAR ECLIPSE

The total lunar eclipse on August 16, 1989, was one of the darkest and most impressive in several years. Gary T. Nowak of Essex Junction, Vermont, thought it was the observing highlight of the year. "I arrived at a friend's house on August 16 with great anticipation," reported Nowak. "We wanted to view the eclipse from his backyard with my 4-inch f/6 refractor. My friend, Russell Chmela, set up his 8-inch SCT as well. We also set up a tripod with a 400mm lens for photography and a tripod with a hub cap to make magnitude estimates of the eclipse. This can be done by looking into the reflection of the sky in

A BRIGHT PERSEID zips past the Alpha Persei association on August 6, 1989. Photo by Clyde Kirkpatrick.

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the hubcap and estimating the overall brightness of the sky.

"Russell used 100x for a closeup view of Earth's shadow, while I used 50x to get a full disk view in the refractor. As we were waiting, the sky became fairly cloudy, although we remained hopeful. We saw first contact through a hole in the clouds. We missed second contact because of clouds, but shortly thereafter the sky cleared and we were unimpeded for the rest of the eclipse. Totality was spectacular: The Moon was a dull, ruddy orange and seemed to cast a spooky glow over the entire sky. We estimated the Moon's magnitude at about 2.3, the same as Gamma Cygni. During this period the Milky Way was clearly visible and we picked out stars as faint as magnitude 6.2 with the naked eye.

"Before we knew it," said Nowak, "the total eclipse became a partial eclipse and washed out the sky with an intense glow. Earth's shadow appeared gray-black as it slowly wandered off of the face of the Moon. After we spent another hour hopping from scope to scope, the Moon exited Earth's shadow and reclaimed its full brilliance. As I

A PORTRAIT OF AN ECLIPSE trails across the sky in this 90-minute camera-and-tripod exposure made on August 16, 1989. Photo by Steve Mathis.

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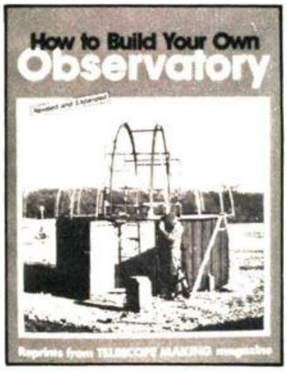

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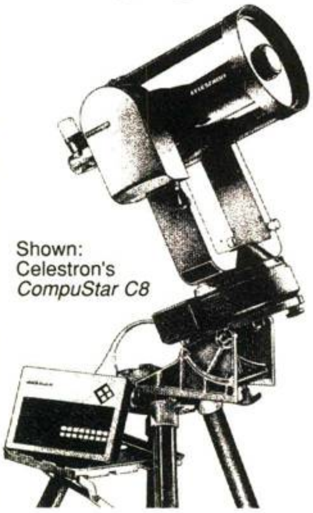

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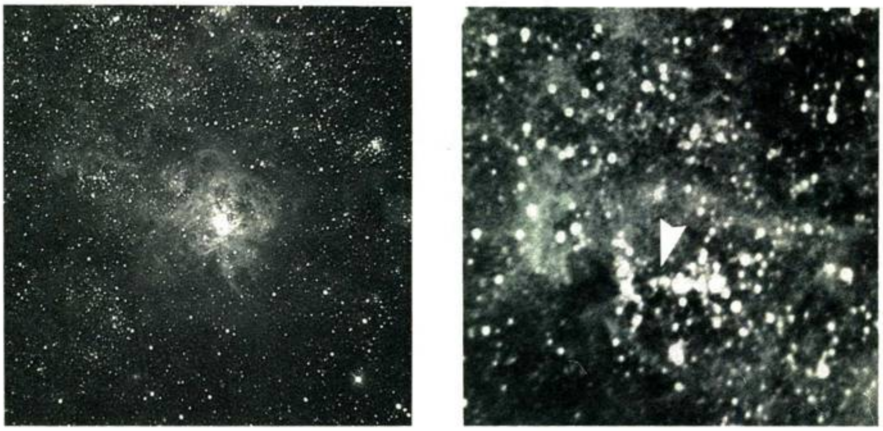
stood underneath it, the Moon's astonishing brightness sent a chill up my spine."



A SUPERNOVA 1987A LIGHT ECHO is visible in this photo made on August 2, 1989. The enlargement shows the immediate region of the supernova and the surrounding shell of gas (arrow). Photos by Steve Quirk.

SKETCHING SATURN

Planetary sketching is an extremely demanding hobby that requires a high-quality telescope, a careful eye for detail, and the willingness to wait for precisely the right moment of steady seeing. Michael Sweetman of Tucson, Arizona, has sketched the planets for several years using his 6-inch f/10 refractor. He welcomes the challenge of seeing and recording on paper atmospheric details smaller than the finest obtainable on photographic film.

"Altogether I made thirty-three observations of Saturn during the 1989 apparition," reported Sweetman. "One of my favorite sketches was made prior to opposition on June 10, 1989, with the 6-inch refractor, using powers of 290x and 435x. Seeing was exceptionally good during this session, allowing me to record the northern belts. These appeared clearly defined in June but were much less detailed and therefore were poorly observed after opposition.

"On August 20, 1989, I made another unusual sketch of Saturn. Again using the 6-inch refractor at 290x and 435x, I made a sketch showing the northern belts as poorly defined and extending only partway across the planet's globe. Color variations in the C ring appeared from time to time as the seeing became crisp and softened.

"I find sketching Saturn extremely relaxing," said Sweetman. "Even though amateurs currently have access to CCDs, photometers, and large Dobso-

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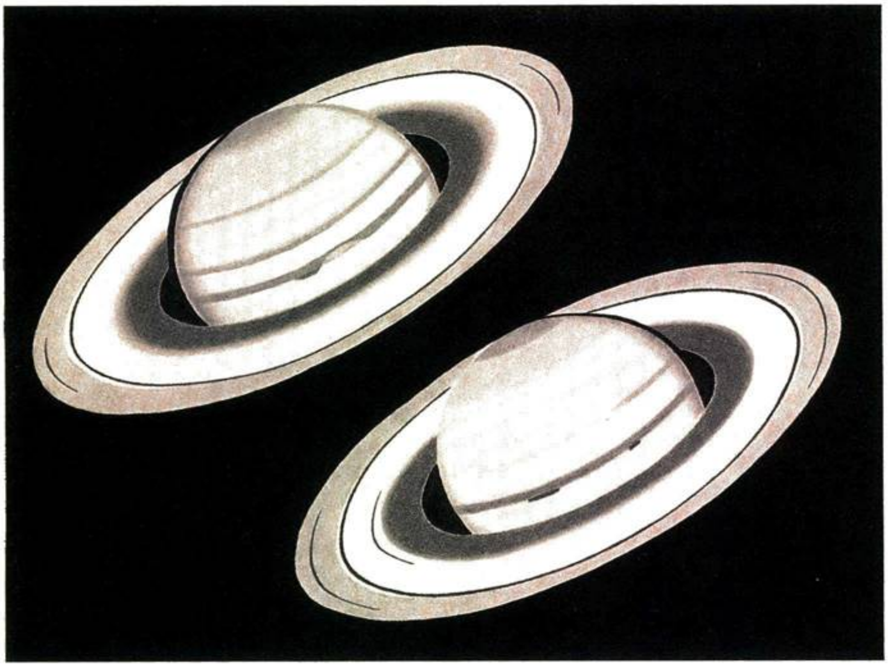
nians, observing planets visually and capturing subtle details on paper holds more allure for me and bridges my experience with that of the past."



SATURN'S ATMOSPHERE changed as the planet went through opposition in mid-1989. Before opposition the planet's northern belts were plainly visible (top). During opposition the belts paled in intensity (bottom). Sketches by Steve Mathis.

ECHOES OF SUPERNOVA 1987A

While experimenting with a roll of the new Ektar 1000 film in August 1989, Australian Steven Quirk apparently became the first nonprofessional astronomer to photograph the light echo from Supernova 1987A.

"I was shooting on an exceptionally transparent night with my 12.5-inch reflector," said Quirk. "After taking sixteen photographs I developed the film and began to study features in the photos to analyze how grainy the film was. I soon noticed that I had recorded a faint image of part of the light echo around Supernova 1987A. After checking with a few sources, I contacted David Malin at the Anglo-Australian Observatory, who confirmed the existence of the nebulosity on the photo. At this time I know of no other amateur photos that show this phenomenon." — *David J. Eicher* □

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WANTED — Armchair astronomer would like to exchange information, documents, and views on non-expanding (static) universe models and observations. Contact Roy Keys, 4405 St. Dominique, Montreal, Quebec Canada H2W 2B2.

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THREE MINUTES OF AIR TIME

When you're waiting for an elevator, three minutes is forever. When you're trying to take a hologram of a Moon rock, three minutes disappears so fast it hardly even happens.

Why three minutes? That was as long as NASA would allow any Moon rock to be exposed to air.

Let me back up a moment. In December 1988 I decided that I wanted my company, Sky Holographics, to holograph a sample of Moon rock and make the hologram available by July 1989, the twentieth anniversary of the first manned lunar landing. We are based in Britain, so when I started searching for a lunar sample I spent much time phoning and writing numerous museums around the United Kingdom and Europe, all without success. Finally, after a great many dead-ends, I got in touch with John W. Dietrich, the Lunar Sample Curator at NASA's Johnson Space Center in Houston, Texas.

John was enthusiastic about the idea, but said that we would have to carry out the holographing in the Johnson laboratories under strict controls. With this fully understood, John started the paperwork within NASA to get us permission.

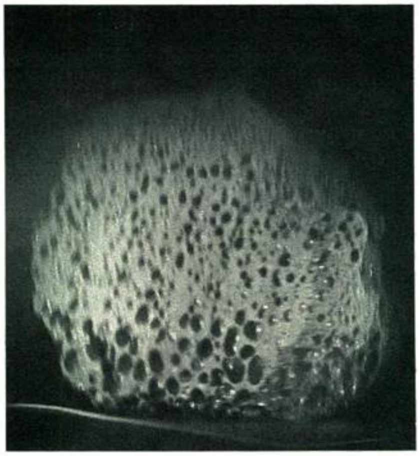
In the meantime I was sent photographs of the nitrogen-filled cabinets in which the samples are housed. The cabinets, designed to prevent contamination, are constructed from stainless steel and measure approximately 2 feet wide by 6 feet long by 3 feet high. Each cabinet sits on a 3-foot-high bench.

At one end of the cabinet an entry port lets investigators load and unload samples. A viewing port approximately 2 feet by 2 feet by 1 foot is at the opposite end. The two remaining sides of the cabinet are constructed of Lexan, an acrylic plastic. Mounted in one of the Lexan windows are four glove ports through which the laboratory personnel handle the rocks.

I needed just one look at the photos to know that it was going to be virtually impossible to holograph the rocks inside their cabinets. The highly reflective stainless steel walls would bounce stray laser light all around, completely fogging the holographic plate.

I expressed my concern to John during a telephone conversation, but I still felt it was worth a go. John finished the conversation by saying that he might be able to get around the problem. And he certainly did. During our next conversation he informed me he had obtained permission to remove three rock samples from their nitrogen cabinets so we could holograph them in the open. However, there was a catch: To reduce the chance of contamination by terrestrial materials, each rock could be exposed to the air for only three minutes.

Since my deadline was approaching, John and I agreed that I should fly to Houston to sort out the problems and evaluate the working conditions. Richard Norris, the managing director of Sky Holographics, got busy obtaining the relevant security passes so we could get into the Johnson Space Center. This involved a security clearance by the British Ministry of Defense as well as by NASA. After a considerable amount of chasing by Richard and John, the clearances were finally issued.



HOLOGRAPHING A MOON ROCK turned out to incur virtually every one of a holographer's worst nightmares.

Richard and I arrived at Johnson at 8 a.m. on April 5, 1989. We collected our passes and made our way to Building 31, where we were met by John. After he introduced us to Chuck Meyers, the center's Contamination Control Officer, we got a guided tour of the public displays. We were then taken to laboratories on the second floor, which are environmentally controlled and totally dust-free.

To enter the main section of the labs in which the nitrogen cabinets are located, you first pass through two changing areas and one air shower. You enter the first changing room from the outer staging area, this being where equipment is cleaned. The door between these two areas has an electronic security system, as do the two doors that exit from the first changing area into different sections of the main laboratories.

Once in the first changing area, you put paper boots on over your outdoor shoes. You then sign the visitors' book before entering the second changing area. In this room you are given what John calls "bunny suits," basically a pair of overalls, a hat, gloves, and a third pair of shoes to go over the two pair you are already wearing. At this point you are covered almost entirely from head to foot.

Next comes the air shower in which you stand for sixty seconds as clean air flows down over you, "washing" away loose particles of dust. Finally, we entered the main laboratory area and spent the rest of the day looking through them and in meetings with John and Chuck.

We were told what materials we could not bring into the laboratory areas. The two main no-go elements are gold and lead. This caused our first major problem because all our optical equipment is mounted on stands that contain a lot of lead for stability. The only remedy was a total remake of much of our equipment, which we did when we returned home.

On April 30, Richard and I flew back to Houston with 300 pounds of now lead-free holography equipment. It was not until 8 a.m. on Monday, May 1, however, that we could get into NASA to unload. With the exception of the large collimating mirror, which due to its fragile nature had to be unpacked within the main building, all the equipment was inspected and thoroughly cleaned in the loading bay by Johnson personnel before it was allowed anywhere near the main laboratory area.

Once everything had been moved into the experimental laboratory, I set up to take a test shot on a model of the first rock we were to holograph. The experimental laboratory is a part of the main lab designed expressly for out-of-the-ordinary experiments on Moon rock samples. In this area the strict rules governing the lab may be relaxed to a certain extent at the discretion of John and his team. One thing they never compromise, though, is security: We were accompanied by two Space Center personnel whenever we were in the lab complex.

By 3 p.m. we had all the equipment set up for the first test shots using the model rock as a sample. Holography uses a laser to illuminate the object with a coherent beam of light. Mirrors send the laser beam around the setup and at a given point the beam is divided in two. From here the first beam is expanded by a lens and filter and aimed at the film to form what is known as the reference beam.

The second beam, called the object beam, is split once more into two beams that are directed to shine onto the rock from two directions. The hologram is formed by the interaction of the reference beam and the reflection of the object beam from the surface of the sample.

The key to making a successful hologram is keeping all the optical elements perfectly in position. The slightest vibration is enough to totally destroy the effect.

As soon as I developed the first test hologram I knew we had very serious problems. Although John had explained that the building that houses the labs was designed to be extremely rigid and had very little vibration, what little there was was far too much. Even John shifting his weight from one foot to the other caused intolerable vibrations. The fact that the building was not as stable as first thought seemed to surprise the NASA people more than anyone else.

I therefore rearranged the equipment to form an interferometer that could tell us exactly how bad the problem was. The biggest culprit turned out to be a sub-audible vibration coming from the ventilation system, part of which was directly below where we were working. With that identified, we called it quits for Day 1.

The next day John arranged for the ventilation system to be turned off when we needed to make an exposure. Although this reduced the vibration, we now began to detect *all* motion in the vicinity — even movement elsewhere in the building was registering! We therefore had to devise a makeshift optical table to isolate the equipment.

This was when the Space Center staff really got busy. I explained to them what was needed and within half an hour they had an inflatable mattress on the floor to act as a vibration dampener. Then we placed a 4 by 8 foot by 1/4-inch-thick aluminum door on top to make a platform. Next came six half-inflated rubber tires with a 4 by 8 foot by 1 inch aluminum-laminated piece of plywood acting as the table top. This "table" worked well but the mattress and aluminum door caused problems so we removed them. We spent the rest of Day 2 running tests.

On Wednesday, Day 3, I reconfigured the equipment for test exposures. Once again John had all ventilation turned off, the elevator immobilized, and signs put up to prevent anyone from entering the building.

We then discovered a new problem. The holographic film is held in place by vacuum suction, but due to the vibration we were unable to use our own vacuum pump. NASA's pump was not compatible with our plateholder. After everyone worked on the problem, it was clear that the only thing to do was modify the plate, which I did overnight.

At the start of Day 4 I replaced the vacuum plate, which now worked well, and we ran more tests. At 11:30 a.m. we decided the time had finally come to holograph a real Moon rock.

Time suddenly became critical. We had just three minutes to do it. One last time I made sure that the setup was correct. The two technicians who handled the rock samples for the shot removed the first sample from its nitrogen cabinet and placed it in a nitrogen-filled holding bag. After we checked and double-checked everything, they removed the sample from the bag and placed it onto the table. The room lights were turned off and I took two exposures of 3 seconds each in quick succession. Upon developing the holograms I found that at last something had gone right. We now had two good holographic masters of the rock.

When Friday, Day 5 — our last day — dawned, we felt ready for the largest of the rocks. We knew this one was going to create problems because it was a very large gray mass, awkward to handle and position. But now feeling like veterans we successfully managed to get three master holograms of it by mid-afternoon.

Security constraints required us to have all our equipment out of the labs by 4:30 p.m. for the weekend. Under this deadline and emboldened by our success, we decided to go straight ahead with the third rock sample. We got it on the first attempt.

Looking back on the whole experience, the Moon rock project turned out to incur virtually every one of a holographer's worst fears. At the best of times, holography is a tricky subject. I'm delighted that things went as well as they did and very grateful to the Johnson Space Center staff for pulling out all the stops when needed. — *John Bozac* ☐

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The Guide to Amateur Astronomy by Jack Newton and Philip Teece, (Cambridge University Press, 1988), ISBN 0-521-34028-4, hardcover, 327 pages, $24.95.

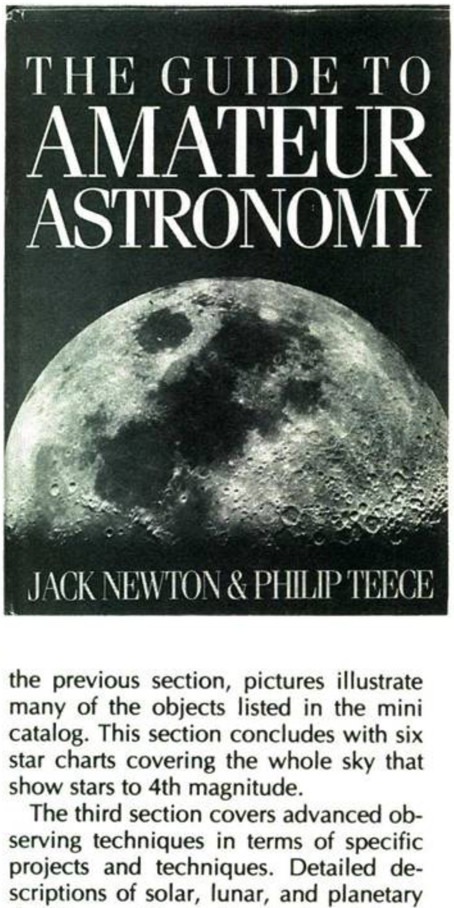
Getting started in amateur astronomy can be a frustrating experience. Trying to learn the sky, the buzzwords, and the various techniques can seem an impossible task. Most people rely on a patient friend to teach them the ropes simply because books on the subject are often too dry and incomplete. But today's amateur astronomer can now turn to *The Guide to Amateur Astronomy* by Jack Newton and Philip Teece, a well-written and well-organized book designed primarily for getting someone started in amateur astronomy. It covers everything from making a telescope to using one, both visually and photographically.

But *The Guide to Amateur Astronomy* is more than an introduction to observational astronomy. The book also offers more advanced information. This gives beginners the material they can grow into while offering experienced observers new challenges and observing programs to explore.

The book is divided into five major sections, each dealing with a different aspect of amateur astronomy. The first section covers the fundamentals of amateur astronomy and begins with a poetic introduction to the night sky. But the poetry quickly gives way to the substance of amateur astronomy. Information on learning the stars and constellations with the naked eye is presented. The tools needed to help in this endeavor, such as star charts, are discussed at length. The topic then moves on to telescopes, mounts, and eyepieces. The authors discuss each type and consider the advantages and disadvantages of each. Tables and charts summarize the text and give additional information on performance.

The first section also covers the basics of astronomical observing with a focus on the different types of objects, both planetary and deep-sky. As for the planetary section, there is information on each planet, where to find it in the sky, how to observe it, and what you can expect to see. The deep-sky portion is organized by type of object. A visual description of each type is accompanied by a photograph to give the reader an idea of what it looks like. This section finishes with techniques on how to find objects and how to sketch them.

The second section is a mini-catalog of objects in the sky. Newton and Teece present the constellations of each season and highlight many of the objects found in those constellations. And because the objects listed are some of the authors' favorites, this isn't just a bland rehash of other catalogs. Provided are each object's designation, coordinates, and a brief description of its appearance in the telescope. The only drawback to this section is that nowhere does it mention what equinox the coordinates are listed in (my guess is 2000.0). As with the previous section, pictures illustrate many of the objects listed in the mini catalog. This section concludes with six star charts covering the whole sky that show stars to 4th magnitude.



The third section covers advanced observing techniques in terms of specific projects and techniques. Detailed descriptions of solar, lunar, and planetary detail are outlined. Also included is information on observing asteroids and meteors.

Moving out of the solar system, the authors discuss double and variable stars. A list of seven showpiece double stars and six binaries is provided. Considering that the authors discuss advanced tools required for serious observations such as micrometers and photometers, this list seems too brief. A larger list for ambitious observers would have been a convenient addition. The same can be said for the list of variable stars, of which only ten stars are provided.

This section closes with a discussion on astronomy clubs and star parties. Those interested in starting a club or reviving an old one will find the information here very useful.

The fourth section deals with astrophotography. All forms of celestial photography and types of equipment are covered. The authors even cover some interesting topics such as how to photograph lightning, that would not fall into the category of celestial photography. This section is heavily illustrated. The authors also cover film selection, film treatment, and darkroom techniques that will help you get the most out of your astrophotos.

The final section of the book covers telescope making, with heavy emphasis on the optics. Consideration is also given to how to build an observatory. Several designs from roll-off roofs to domes are mentioned; even site selection is covered. Illustrations of several telescopes and observatories are included to give the reader an idea of what can be done.

There are two aspects of this book that I found quite interesting, especially since they are absent from most other books. The first is that the authors are cognizant of their Southern Hemisphere counterparts. The mini-catalog lists many southern sky objects, and the section on polar alignment discusses techniques for aligning on the south celestial pole.

The second aspect I found refreshing was the dual approach to amateur astronomy. Currently there is some controversy over the role of the amateur astronomer in professional astronomy. Many amateurs argue that to truly be an amateur astronomer one must do real science. Others believe that to enjoy the stars for what they are is all that is important. But Newton and Teece approach the subject from both angles. There is useful information for the amateur who wants to make a scientific contribution and there is also information for the amateur who just wants to look at the sky and enjoy it.

Jack Newton and Philip Teece have produced an excellent work that all amateur astronomers will find useful and informative. *The Guide to Amateur Astronomy* may well become the standard by which all introductory books to amateur astronomy will be measured. — *Mark J. Coco*

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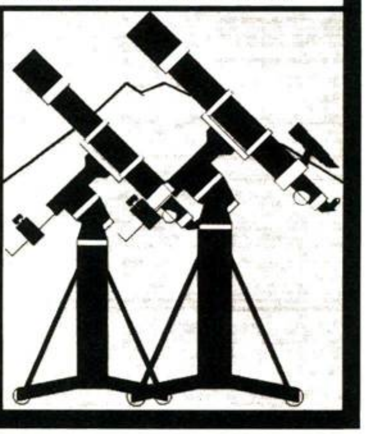

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BOOKS RECEIVED

Amateur Astronomy

Astronomie Du Ciel Profond: Observation — Photographie Atlas by Serge Brunier, (Dunod, 17, rue Remy-Dumoncel, B.P. 50, 75661, Paris Cedex 14), ISBN 2-04-018696-4, softcover, 272 pages, 160 French francs (about $26.00).

Astrophoto VIII: Proceedings, edited by John Sanford, (Orange County Astronomers Publications, 2215 Martha Ave., Orange, CA 92667), softcover, 46 pages, $10.00 ppd. U.S., $12.00 elsewhere, $15.00, air anywhere.

Atlas of Galactic Nebulae volumes 1 and 2, by Thorsten Neckel and Hans Vehrenberg, (Treugesell-Verlag Dr. Vehrenberg K.G., Schillerstrasse 17, D-4000, Dusseldorf 1), ISBN 3-87974-125-5, both volumes are notebook bound; volume 1: 128 pages, 435 photographs, $68.00; volume 2: 158 pages, 470 photographs, $82.00.

Deep-Sky Observing with Small Telescopes by David J. Eicher and the editors of *Deep-Sky* Magazine, (Enslow, 1989), ISBN 0-89490-075-7, softcover, 336 pages, $29.95.

Observing the Constellations: An A-Z Guide for the Amateur Astronomer by John Sanford, (Simon and Schuster, 1989), ISBN 0-671-68924-X, softcover, 176 pages, $16.95.

Practical Ephemeris Calculations by Oliver Montenbruck, (Springer-Verlag, 1989), ISBN 0-387-50704-3, softcover, 146 pages, $24.50.

Stargazers: The Contribution of Amateurs to Astronomy, edited by S. Dunlop and M. Gerbaldi, (Springer-Verlag, 1989), ISBN 0-387-50230-0, softcover, 237 pages, $29.50.

Archeoastronomy

Prehistoric Astronomy in the Southwest by J. McKim Malville and Claudia Putnam, (Johnson Books, 1989) ISBN 1-55566-041-X, softcover, 105 pages, $7.95.

Astrophysics and Physics

Annual Review of Astronomy and Astrophysics, Volume 27, 1989, edited by Geoffrey Burbidge, David Layzer, and John G. Phillips, (Annual Reviews, 1989), ISBN 0-8243-0927-8, hardcover, 773 pages, $47.00.

Dust in the Universe, a conference at the Department of Astronomy, University of Manchester, 14-18 December 1987, edited by M.E. Bailey and D.A. Williams, (Cambridge University Press, 1988), ISBN 0-521-35580-X, hardcover, 573 pages, price unavailable.

Essentials of Modern Physics by Thomas R. Sandin, (Addison-Wesley Publishing, 1989), ISBN 0-201-09256-5, hardcover, 575 pages, $42.75.

Fearful Symmetry: The Search for Modern Physics by A. Zee, (Macmillan, 1989), ISBN 0-02-040911-7, softcover, 322 pages, $9.95.

From Quarks to the Cosmos by Leon M. Lederman and David N. Schramm, (W.H. Freeman, 1989), ISBN 0-7167-5052-X, hardcover, 242 pages, $32.95.

Highlights of Astronomy, as presented at the XXth General Assembly of the International Astronomical Union, 1988, edited by D. McNally, (Kluwer Academic Publishers, 1989), ISBN 0-7923-0280-X, hardcover, 699 pages, $162.00.

Interstellar Matter: Proceedings of the Second Haystack Observatory Meeting, edited by James M. Moran and Paul T. P. Ho, (Harwood Academic Publishers, 1989), ISBN 0-677-21910-5, hardcover, 418 pages, $89.00 ($54.00 Science and Arts Society price).

Nuclear Astrophysics, edited by M. Lozano, M.I. Gallardo, and J.M. Arias, (Springer-Verlag, 1989), ISBN 0-387-50751-5, softcover, 355 pages, $55.90.

Neutrino Astrophysics by John N. Bahcall, (Cambridge University Press, 1989), ISBN 0-521-35113-8, hardcover, 567 pages, $75.00.

Noctilucent Clouds by Michael Gadsden and Wilfried Schroder, (Springer-Verlag, 1989), ISBN 0-387-50685-3, hardcover, 165 pages, $79.50.

Particle Physics and Astrophysics: Current Viewpoints, edited by H. Mitter and F. Widder, (Springer-Verlag, 1989), ISBN 0-387-50699-3, hardcover, 309 pages, $50.80.

The Physical Basis of the Direction of Time by H. Dieter Zeh, (Springer-Verlag, 1989), ISBN 0-387-50930-5, softcover, 166 pages, $35.00.

Reviews in Modern Astronomy: 1 — Cosmic Chemistry, edited by Gerhard Klare, (Springer-Verlag, 1989), ISBN 0-387-50412-5, hardcover, 253 pages, $33.10.

Data Processing

Artificial Intelligence Techniques for Astronomy, edited by Andre Heck, (Observatoire Astronomique, 11 rue de l'Universite, F-67000 Strasbourg, France), ISBN 2-906361-04-6, softcover, 79 pages, $20.00.

Electronics for Physics Experiments Using the Apple II Computer by John W. Snider and Joseph Priest, (Addison-Wesley Publishing, 1989), ISBN 0-201-17598-3, softcover, 289 pages, $27.95. (Includes program disk.) ☐

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Episode 10: The Edge of Forever, 60 min.
Episode 11: Persistence of Memory, 60 min.
Episode 12: Encyclopaedia Galactica, 60 min.
Episode 13: Who Speaks for Earth?, 60 min.
A Dialogue: Carl Sagan & Ted Turner, 60 min.

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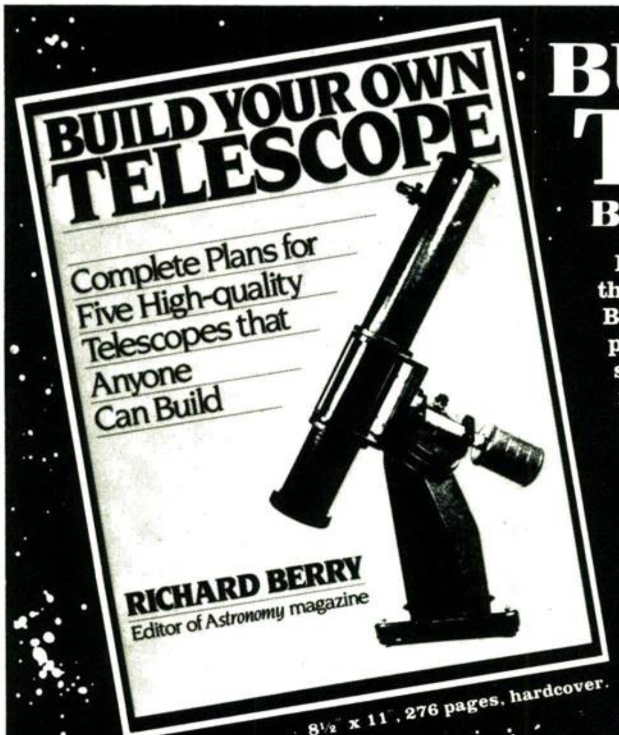
FOR SALE — Meade 2080 LX3 with standard factory equipment, declination motor, dual-axis controller, and 20mm and 7mm eyepieces. Mint condition. $1,050. Will deliver within 200 miles. Contact Jay Crawford, RD1, Box 311A, Quakertown, PA 18951. Phone (215) 538-7589.

FOR SALE — *Review of Popular Astronomy.* September 1961-August 1969 (1963 missing). *Star & Sky.* January 1979-February 1981. *Astrograph.* February 1974-January 1980. All for $100 plus shipping. Contact Sydney Levitan, 4 Stanyon Road, York, Pa 17403. Phone (717) 741-1084.

FOR SALE — Celestron SP-C8 tube assembly with Starbright coatings, 6x30 finder, case, and full aperture solar filter. $575 plus shipping. Celestron C-102 tube assembly and 6x30 finder. $375 plus shipping. Contact Larry Pierce, 500 West Street, Sullivan, IN 47882. Phone (812) 268-3601.

WANTED — Pen pal interested in astronomy and science fiction. Contact John Paul Clark #25026, P.O. Box 30 (0-1), Pendleton, IN 46064.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OBSERVERS' ACCESSORIES

Vibration Suppression footpads, (Celestron International, 2835 Columbia St., Torrance, CA 90503; (213) 328-9560), $72 per set of three.

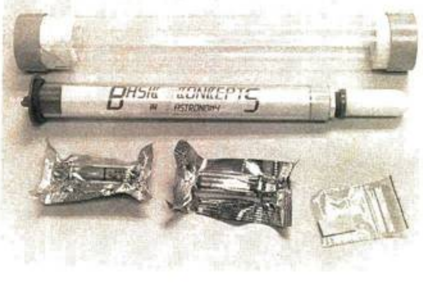
Celestron's new footpads are designed to absorb vibration and thereby reduce the image shake seen in the eyepiece when the observer touches the telescope. They are made of nylon and silicone rubber, measure 3 1/4 inches across, and stand 1 1/8 inches high. The user places them underneath a telescope tripod's feet while observing. Three low knobs on the underside of each footpad afford positive contact with the ground. The rubber is intended to retain its motion-damping properties down to temperatures as low as –20° F.

VIBRATION-ABSORBING footpads from Celestron are designed to make observing easier by reducing image shake.

Dewmaster moisture absorber, (Basic Concepts in Astronomy, 11278 E. Meadow Glen Way, Escondido, CA 92026), $39.95 plus $4.95 shipping and handling.

The Dewmaster is designed to remove moisture from the air inside a Schmidt-Cassegrain telescope during storage. (It is not intended to prevent any dewing that may occur while the telescope is in use.) After an observing session, the user inserts the Dewmaster by removing the telescope's right-angle eyepiece holder. The Dewmaster is held in place by tightening the threaded collar on the backplate of the telescope.

The Dewmaster kit comes with airtight storage tube, Dewmaster holder, and three disposable cartridges, each good for several months of use (less in highly humid climates). Additional cartridges are sold in sets of three for $9.95 plus $2.95 shipping and handling.



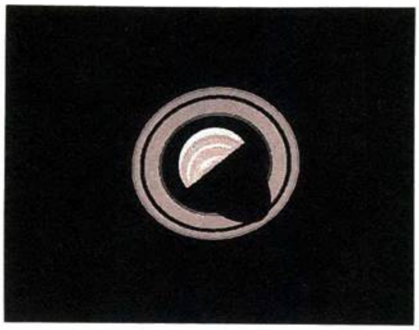
THE DEWMASTER can absorb the moisture trapped inside a stored telescope and prevent internal condensation.

ASTRONOMICAL SOFTWARE

The Dance of the Planets, (Applied Research and Consulting, P.O. Box 1974, Loveland, CO 80539-1974; (303) 663-3223), $145.00.

The Dance of the Planets is software that displays planetary configurations and appearances for all dates from 999 BC to AD 9999. The program lets the user view the solar system from a distance or zoom in to view any particular planet from any angle. In addition to logging 1,300 comets, *Dance* also includes 4,100 asteroids and can display their orbits. Some 1,500 background stars are presented in six magnitude steps. Glasses with red and green lenses are provided for stereo viewing of comet orbits.

Dance requires an IBM PC or PS/2 (or compatibles), 512K of RAM, and EGA or VGA graphics. The publisher notes that a math co-processor will speed performance by a factor of 5, but is not necessary to run the software. *Dance of the Planets* is supplied on either 5¼- or 3½-inch disks. ☐



A SIMULATED SATURN is shown from an unusual perspective by *The Dance of the Planets* software.

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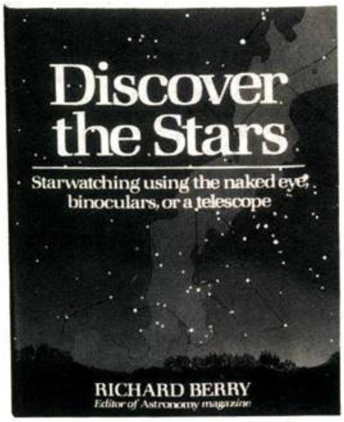
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Meetings and Events

January 13
Astronomy Day 1990, Pine Mountain, Georgia. Sponsored by the Patterson Planetarium and Callaway Gardens. Contact: Patterson Planetarium, 2900 Woodruff Farm Road, Columbus, GA 31907. Phone: (404) 568-1730.

January 25-28
6th Annual Winter Star Party, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

February 22
Galileo: A Jovian Odyssey, Toronto, Ontario. Sponsored by The Planetary Society. Contact: Hema Murty, 5949 Yonge Street, #506, Willowdale, Ontario, Canada M2M 3V8. Phone: (416) 225-9143.

March 14
New England Astronomy Teachers' Organization, Cambridge, Massachusetts. Contact: Dr. Darrel Hoff, Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, or James C. Kernohan, NEAT, 170 Centre Street, Milton, MA 02186. Phone: (617) 698-7800.

March 17
Electronics-Oriented Astronomy 3, Chapman College, Orange, California. Sponsored by the Orange County Astronomers. Contact: John Sanford, 2215 Martha Avenue, Orange, CA 92667.

March 22-25
3rd Annual Chiefland Star Party, Chiefland, Florida. Sponsored by the Tampa Area Astronomy Society. Contact: John Novak, 9890 82nd Street North, Largo, FL 34627. Phone: (813) 392-4669 or (904) 493-9036.

April 24-27
27th Space Congress, Cocoa Beach, Florida. Sponsored by the Canaveral Council of Technical Societies. Contact: Canaveral Council of Technical Societies, P.O. Box 321333, Cocoa Beach, Florida 32932.

May 20-28
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: TSP Registrar, Department A, P.O. Box 386, Wylie, TX 75098.

May 22-27
The 10th Annual International Space Development Conference, San Antonio, Texas. Sponsored by the National Space Society and the Southwest Research Institute. Contact: Carol A. Luckhardt, Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78228-0510. Phone: (512) 522-3823.

July 13-15
Symposium on Automated Telescopes and Global Networking, Boston University, Boston, Massachusetts. Contact: Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

July 13-18
Meeting of the Astronomical Society of the Pacific, Boston University, Boston, Massachusetts. Contact: Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

July 14-15
The Universe in the Classroom, Boston University, Boston, Massachusetts. Contact: Workshop Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

July 8-21, 1991
Research Amateur Astronomy Symposium, La Paz, Baja California Sur, Mexico. Contact: Corporation for Research in Amateur Astronomy, P.O. Box 16542, San Francisco, CA 94116.

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. ☐

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WANTED — Worldwide correspondence with teens interested in astronomy or science related subjects. Will respond to all letters. Contact Deanna Gaeta, 20009 Esquiline Avenue, Walnut, CA 91789.

FOR SALE — Meade model 6600 6″ reflector, equatorial mount, and 25mm and 9mm eyepieces. Excellent condition. $400. Contact James Walker, 419 Cove Creek Road, East Gadsden, AL 35903. Phone (205) 492-1178.

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FOR SALE — Meteorites. Odessa, Texas iron, 158.5 grams. Canyon Diablo iron, 73.5 grams. Huckitta cut and polished, 12 grams. Pampa "C" stone. Half-pound tektites. *Thunderstones.* $250 including shipping. Contact Steve Donnelly, 14965 Ceres Avenue, Fontana, CA 92335. Phone (714) 350-0547.

FOR SALE — Odyssey 13.1″ f/4.5. Like new. Many extras. $400. Contact Steve Childers, 778 New London Road, Hamilton, OH 45013. Phone (513) 863-6231.

FOR SALE — ASTRONOMY from August 1973. Complete set, mint condition. *Sky & Telescope*. Ten assorted issues from 1988. All in slipcases. Best offer over $300, shipping included. Also, list of astronomy books (send SASE). Contact K. Jons, 18405 Newell, Shaker Heights, OH 44122. Phone (216) 752-9128 (evenings).

WANTED — Thirty-four-year-old beginner seeks correspondence worldwide with others interested in astronomy and telescope making. Will reply to all letters. Contact G. Allan, 1025 Cavalier Drive, Winnipeg, Manitoba, Canada R2Y 1E2.

FOR SALE — Meade model 826 8″ f/6 reflector with clock drive, setting circles, dust covers, two eyepieces, and Barlow. Very good condition. $600. Contact Diana Nevins, 331 West College Avenue, State College, PA 16801. Phone (814) 237-2251 (evenings).

WANTED — Newspaper articles, books, photographs, video tapes, and other related material dealing with Jupiter, Saturn, Uranus, Neptune, Pluto, Planet X, and possible extraterrestrial solar systems. Forward complete list. Contact Rob Rosenbrook, 211 West McDevitt, Jackson, MI 49203.

FOR SALE — Goto 8cm f/12.5″ "ED" apochromatic equatorial refractor with 12 volt DC pulse motor drive, hand control unit, pier, and accessories. Superb optical performance. Brand new. Must sell. $4,100 includes shipping. Contact Joseph C. Nastasi, P.O. Box 59, Wilmington, VT 05363. Phone (802) 368-7570.

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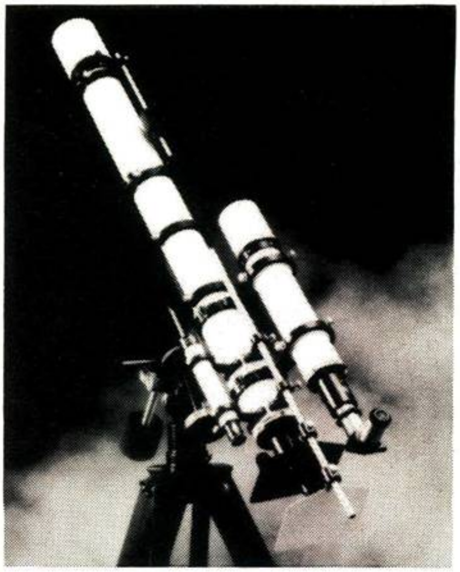

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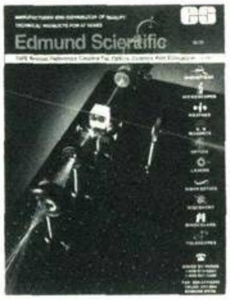

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Readings and Resources

Realm of the Hottest Stars (page 22)

Stars and Their Spectra by James B. Kaler, (Cambridge University Press, 1989). Kaler explains the fundamental properties of stars, the structure of atoms, and the formation of spectra. The text covers each star type and includes discussions of unusual stars.

Deep Sky, Summer 1986, (Kalmbach Publishing Co.). A special issue on planetary nebulae. In addition to listing over 250 planetaries that can be observed with amateur telescopes, David Kratz discusses the astrophysical properties and observability of the central stars of planetary nebulae.

The X-ray Sun (page 32)

The Restless Sun by Donat G. Wentzel, (Smithsonian Institution Press, 1989). A highly readable work on all aspects of the Sun, including x-ray properties and solar activity.

Contemporary Astronomy, fourth edition, by Jay M. Pasachoff (Saunders College Publishing, 1989). This astronomy text includes a chapter on "The Sun: A Star Close Up," which provides a particularly cogent description of the energetic Sun and how astronomers study the Sun at x-ray wavelengths.

Into the Night (page 42)

The Restless Sun by Donat G. Wentzel, (Smithsonian Institution Press, 1989). This readable introduction focuses on the Sun as a star but includes a major section on the solar wind.

Shake-Enders (page 64)

"The Mount of Gibraltar" by Rick Shaffer, ASTRONOMY, August 1988. Describes some "home remedies" to improve a mounting's stability.

The Art of Seeing (page 66)

Planets and Perception: Telescopic Views and Interpretations, 1609-1909 by William Sheehan, (University of Arizona Press, 1988). A fascinating essay by a psychologist/amateur astronomer that analyzes seeing on both physiological and psychological grounds.

Supernova Remnants (page 72)

Deep Sky Observing with Small Telescopes by David J. Eicher and the editors of *Deep Sky,* (Enslow Publishers, 1989). An observing manual with a chapter on bright and dark nebulae that contains historical, physical, and observational material on supernova remnants.

Explore the Hyades (page 78)

Burnham's Celestial Handbook, Volume 3, by Robert Burnham, Jr., (Dover Publications, 1978). The section on the Hyades contains additional astrophysical information on this star cluster. ☐

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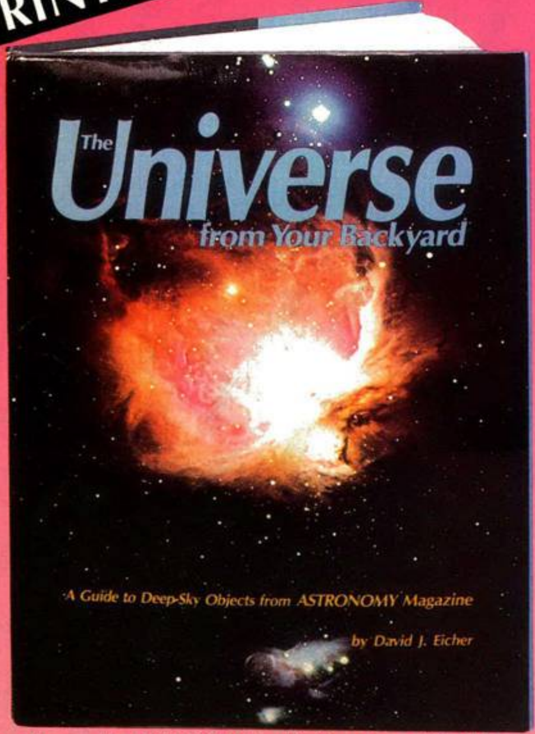
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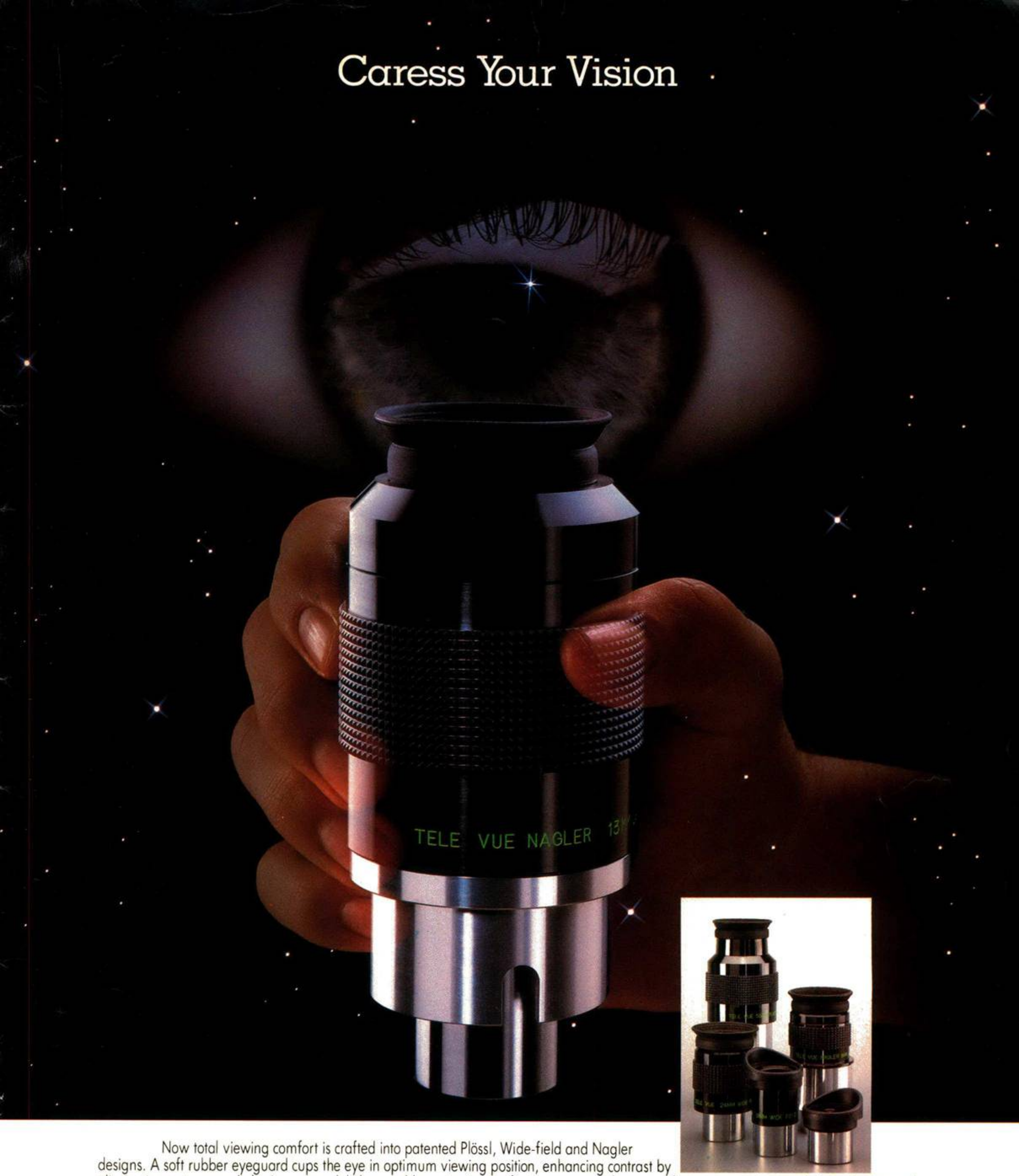

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